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16. ABSTRACT

The development and application of a methodology for evaluating the environmental and economic impacts of placing marginal, submarginal, and Soil Bank land in crop production is described. Environmental impacts were measured by quantifying the increased environmental loadings of sediment, nitrogen, and phosphorus and by estimating the potential environmental impact of pesticides. Economic consequences considered included changes in net farm income and aggregate impact on the state's economy. Although no attempt was made to place a dollar value on environmental consequences, these impacts can be weighed against the economic impacts in a tradeoff fashion as a measure of social costs and benefits resulting from increased production on new cropland.

The developed methodology was applied to the state of Georgia for the period 1973-1976. The pollutants generated annually from each hectare of converted crop production land during the period were estimated to be 11.9 metric tons of sediment, 8.1 kilograms of nitrogen loss (excluding leaching), and 10.5 kilograms of phosphorus loss. Net farm income increased an estimated $61 per hectare annually.

Methodology used in this study could be used in similar studies in other areas of the United States. Much of the required data is already available in other areas.

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by

Fred C. White
James E. Hairston
Wesley N. Musser
H. F. Perkins
J. F. Reed
University of Georgia
Athens, Georgia 30602

Grant No. R804510-01

Project Officers

Thomas E. Waddell
George W. Bailey
Technology Development and Applications Branch
Environmental Research Laboratory
Athens, Georgia 30605

ENVIRONMENTAL RESEARCH LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
ATHENS, GEORGIA 30605

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FOREWORD

As environmental controls become more costly to implement and the penalties of judgment errors become more severe, environmental quality management requires more efficient analytical tools based on greater knowledge of the environmental phenomena to be managed. As part of this Laboratory's research on the occurrence, movement, transformation, impact, and control of environmental contaminants, the Technology Development and Applications Branch develops management and engineering tools to help pollution control officials achieve water quality goals through watershed management.

Agricultural sources contribute significantly to water pollution problems in many areas of the United States. These problems are of particular concern as more farm land is brought into production to meet the demands of expanding domestic and world markets. This report presents a methodology for analyzing the environmental and economic impacts of incresed crop acreage and applies it to the state of Georgia. The methodology was developed as a tool for decision-makers involved in formulating public policy concerning levels of agricultural production as well as evaluating environmental standards for agriculture.

David W. Duttweiler
Director
Environmental Research Laboratory
Athens, Georgia

ABSTRACT

This project, a joint effort of the Agricultural Economics and Agronomy Departments at the University of Georgia, was designed to develop and apply a methodology for evaluating the environmental and economic impacts of placing marginal, submarginal, and Soil Bank land in crop production. Environmental impacts were measured by quantifying the increased environmental loadings of sediment, nitrogen and phosphorus and by estimating the potential environmental impact of pesticides. Economic consequences considered include changes in net farm income and aggregate impact on the state's economy. Although no attempt was made to place a dollar value on environmental consequences, these impacts can be weighed against the economic impacts in a tradeoff fashion as a measure of social costs and benefits resulting from increased production on new cropland.

The methodology developed in this study was applied to the state of Georgia for the period 1973-1976. During this period 74.5 thousand hectares of marginal, submarginal, and Soil Bank land in Georgia were placed in crop production. This change represents only a small fraction of land in these categories that could potentially be converted to crop production. If these land use changes prove to be profitable over a period of years, thereby validating the conversion decisions, more of this land would be expected to be converted to crop production in the future. The pollutants generated annually from each hectare of this land, on the average, are estimated to be 11.9 metric tons of sediment, 8.1 kilograms of nitrogen loss (excluding leaching), and 10.5 kilograms of phosphorus loss. Net farm income increased an estimated $61 per hectare annually. Aggregate personal income for the state was estimated to increase $2 for each one dollar increase in net farm income. Methodology used in this study could be used in similar studies in other areas of the United States. Much of the required data is already available in other areas.

This report was submitted in fulfillment of Grant No. R804510-01 by the University of Georgia under the sponsorship of the U.S. Environmental Protection Agency. This report covers the period July 1, 1976, to August 31, 1978, and work was completed as of August 31, 1978.

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SECTION 1

INTRODUCTION

Farmers in the United States responded to the favorable profit situation for agricultural field crops during the 1973-1976 period by increasing acreage of a number of commodities. As a result, Soil Bank, marginal, and submarginal land that was formerly not in cultivation is now being used for crop production. This increased agricultural production provided benefits to the nation in increased domestic supplies and/or increased quantities of agricultural commodities for export. This increased production, however, also has environmental effects, which are costs to society that are not accounted for in the cost-benefit calculations of farmers. Increased agricultural production results in additional fertilizers and pesticides that may place additional pressure on the waste assimilative capacity of the ecosystem. If the incremental land in crop cultivation is more subject to erosion and runoff, the environmental impact of the increased production is compounded.

Past research by agricultural economists has typically not emphasized the linkage between level of agricultural production and environmental quality. In fact, many aggregate studies of agricultural nonpoint source pollution assume that crop acreage is constant (Wade and Heady, 1977; Alt, Miranowski and Heady, 1979). Even studies that allow adjustment of crop acreages confine their analysis to reallocation of crop acreages among various crop alternatives, including hay. In addition, these studies have not considered alternative levels of demand for agricultural commodities and alternative government programs that caused the recent increases in agricultural production (Horner, 1975; Taylor and Frohberg, 1977; Osteen and Seitz, 1978). Studies of agricultural price programs, which have been concerned with the level of agricultural production, have likewise ignored the environmental effects of level of agricultural production. For example, a recent comprehensive review of research on agricultural policy does not mention environmental effects (Brandow, 1977). Thus, the environmental impacts of alternative levels of agricultural production have been a relatively neglected area of research.

Georgia has many desirable features as a case study for measuring the environmental impact of increased crop acreage. Its land resources are made up of a large number of soil series with widely divergent erosion potentials. The land use configuration is balanced between forest, pastures, and cultivated crops. In addition, the cultivated land is allocated to a large number of crops relative to other states. The combination of diverse land resources and uses results in a variety of potential environmental loadings from changes in land use. Development of a methodology to analyze the environmental impact of increased crop acreage in Georgia, therefore, would provide useful information for a number of situations.

Such information will include geographic dispersions of increased amounts of pesticide and fertilizer used and selected environmental loadings resulting from using Soil Bank, marginal, and submarginal lands for crop production. While incorporating the environmental effects of increased crop production into a cost-benefit framework is beyond the scope of this study, public decision makers need this type of information to consider the full consequences of their decisions. Information on environmental loadings from additional crop acreage may influence public policy decisions concerning levels of agricultural production as well as environmental standards for agriculture. In particular, such information should provide some insight into tradeoffs between environmental policies dealing with control of nonpoint source water pollution and agricultural production policies dealing with the land base used for crop production.

OBJECTIVES

The principal objective of this report is to present a methodology to evaluate the environmental and economic impact of placing Soil Bank, marginal, and submarginal land in crop production. Specific objectives include:

(1) Develop a methodology that can be used to:

(a) Estimate the recent and potential changes in land use by major land classifications and soil associations;

(b) Identify crop yields and input usage, with particular attention to fertilizers and pesticides, for selected row crops by major land classifications and soil associations;

(c) Estimate the environmental loadings of soil, pesticides, and plant nutrients in streams, lakes, and estuaries from various land uses of major land classifications and soil associations;

(d) Assess the environmental impact of recent changes in land use with attention to net changes in environmental loadings and their impact on dimensions of environmental quality;

(e) Assess the economic impact of recent land use changes; and

(2) Apply the methodology, as a case study, to the state of Georgia.

ORGANIZATION OF THE STUDY

Section 2 includes conclusions from the study related to both its methodology and empirical application. Section 3 discusses and evaluates the methodology used in this study to estimate the environmental and economic impact of placing marginal, submarginal, and Soil Bank land in crop production. The remaining sections of the report deal with the empirical application of the methodology to the state of Georgia. Section 4 presents information on Georgia land resources, including a geographic delineation of the state by Land Resource Areas (LRAs). Data presented in subsequent sections are reported according to these LRAs. Changes in land use patterns and input usage for the period 1973-1976 are analyzed in Section 5. That analysis considers changes in row crops, pasture, and forest land. Sections 6 and 7 analyze the environmental and economic impacts, respectively, of placing marginal, submarginal and Soil Bank land in crop production in Georgia for the 1973-1976 period.

SECTION 2

SUMMARY AND CONCLUSIONS

METHODOLOGY

Procedures were developed for delineating and characterizing land resources. The basic unit of analysis used in this study was the Soil Resource Group (SRG). Physical properties used to calculate erosion and runoff were determined for each SRG. Soils were classified as suitable for cultivation, marginal, and submarginal on the basis of the Soil Conservation Service land capability classification system. The advantage of this classification system is that secondary data are readily available. In order to focus on other land classification systems that might account for such factors as technical, aesthetic, economic, environmental and social variables, a completely new inventory of land resources would have to be taken. Land identified as Soil Bank land in this study was that land previously diverted from crop production under the Conservation Reserve Program (CRP). This category is of special interest because a large portion of this land could have been converted to crop production in response to favorable farm prices experienced in the 1973-1976 period.

Land use changes by SRGs and land use patterns were estimated from secondary data and surveys. The Conservation Needs Inventory (CNI) (U.S. Department of Agriculture, Soil Conservation Service, 1970) provided benchmark information on base land use patterns. Changes in land use patterns were estimated from U.S. Department of Agriculture statistics on crop acreage, surveys of Agricultural Stabilization and Conservation Service and Cooperative Extension Service, and actual field surveys. Changes in land use on Soil Bank land were estimated using survey response from participants in the CRP.

Input-output levels for major agricultural and forestry uses of different types of land were synthesized from existing compilations of agronomic and agricultural economic data for major soil groups. Representative input-output levels in a budgetary framework were developed. Use of fertilizers and pesticides for selected crops on various soils in Georgia was of particular interest in considering potential environmental impacts. In addition, these soils were characterized according to factors affecting erosion. After land use changes were determined, quantities of fertilizers and pesticides used were estimated.

Major attention was focused on estimating the net changes in environmental loadings of sediment, pesticides, and fertilizers. Sediment yield for each SRG was based on estimates of sheet and rill erosion by applying the universal soil loss equation (USLE) and sediment delivery ratios based on size of drainage area and soil texture. Estimated runoff, estimated sediment yield and fertilizer application rates were used to determine nitrogen and phosphorus losses. Evaluation of pesticides was based on an index of potential environmental impact. The relative impacts of environmental loadings on various dimensions of environmental quality were assessed only at the conceptual level.

It is extremely difficult to thoroughly analyze all the environmental costs that may result from placing forest and pasture land in crop production. The ubiquitous nature of the externalities that result from increased environmental loadings contribute to the difficulty of conducting a complete, thorough analysis. Data needs for such a broad study would be immense. Even if many of these costs were accounted for and measured, political decisions that consider the distribution of impacts would be necessary to compare benefits of increased crop production with environmental costs. Consequently, environmental loadings are estimated in this study rather than environmental costs.

The net economic benefits of changes in land use patterns were assessed with particular attention given to estimating the incremental value of agricultural production, net farm income, and the secondary impact on the economy. Procedures were developed to estimate production and net farm income for selected crops, pastures and forests. An econometric interindustry model was developed and used to estimate the effect of a change in agricultural production on aggregate personal income and employment.

This methodology could be utilized in similar studies in other areas of the United States. Most of the data required in the study is either collected in all areas of the country or should be available as an adjunct to normal state agricultural research and extension. The major advantage of the methodology is that the data are largely secondary so that time and resources required for data collection are minimized. The methodology also has the advantage of being linked to data which represents actual behavior on land use, crop yields, pesticide and fertilizer use. In this study, only state wide data were available on a number of economic variables which were utilized to estimate net farm income and input use. In some states, more sub-state data would be available, which would improve the accuracy of components of the research. The major weaknesses of the methodology relate to the large number of assumptions necessary to implement the procedures without survey data. Unfortunately, data were unavailable to validate most of these assumptions in this study. Before the methodology is employed on a wide scale, a follow-up study would be advisable to validate these assumptions. Such a study would contrast results from general surveys with results from the assumptions involved in this methodology. The primary data necessary to validate the methodology are discussed in Section 3. Such a future study would be useful in delineating which assumptions are a good approximation and which areas of the methodology should be supplemented with primary survey data.

It must be stressed that this methodology has been designed to provide information for policymakers on the nature and approximate magnitude of economic and environmental variables associated with land use changes at an aggregate level. Many of the possible biases in the methodology at the micro level probably counter affect each other at the macro level. If similar information was required for a planning model either at the state or substate level, the methodology must be validated in a follow-up study to provide confidence for analytical purposes.

EMPIRICAL APPLICATION

This study has attempted to quantitatively measure the environmental and economic impacts of placing marginal, submarginal, and Soil Bank land in crop production in Georgia. It was estimated that 74.5 thousand hectares of such land was placed in crop production in Georgia during the 1973-1976 period. The application of the methodology indicates that substantial environmental loadings of sediment, pesticides, and fertilizers would result from new crop production on marginal, submarginal, and Soil Bank land. The pollutants generated annually from each hectare of this land in crop production, on the average, are estimated to be 11.9 metric tons of sediment, 8.1 kilograms of nitrogen loss (excluding leaching), and 10.5 kilograms of phosphorus loss. However, considerable variation exists among subclasses of these lands. For example, the increased annual sediment yield per hectare from this new cropland ranged from 0.74 to 32.41 metric tons in different LRAs.

Increased pollution also varied between marginal and submarginal land and cultivatable Soil Bank land: the state average for loss of nitrogen per hectare was 7.16 kilograms on marginal and submarginal lands and 9.13 kilograms on cultivatable Soil Bank land. The higher average for cultivatable Soil Bank land resulted from the relative concentration of new cropland in LRAs more subject to nitrogen loss; for most LRAs, the nitrogen loss was smaller for cultivatable Soil Bank land than for marginal and submarginal land. The same difference between these two categories also existed for sediment and phosphorus loss. These results indicate that the conventional marginal and submarginal classification is not necessarily a good index of pollution from crop production. For control of agricultural pollution, examination of broader dimensions than conventional soil conservation classification will be necessary.

Erosion appears to be a key factor that affects environmental loadings of pollutants from cropland converted from marginal, submarginal, and Soil Bank land in Georgia. First, the magnitude of erosion from crop production activities on marginal, submarginal, and Soil Bank land is generally higher than on land classified as suitable for cultivation. Secondly, soil loss from cropland may carry with it nitrogen, phosphorus, and pesticides. Chemical loss could be reduced considerably in many cases with a reduction in erosion.

Even without being bound to soil particles, pesticides and nitrogen can move away from application sites through leaching and runoff. In Georgia, runoff and leaching is only slightly higher on marginal, submarginal and Soil Bank land than on land classified as suitable for cultivation.

Increasing crop acreage (thus, crop production) has substantial beneficial economic impacts that must be weighed against increased environmental loadings. The 74.5 thousand hectares of marginal, submarginal, and Soil Bank land placed in crop production during the 1973-1976 period increased crop production $23.6 million annually. Net farm income increased $4.5 million in aggregate or $61 per hectare annually. Increased crop production has a multiple impact on Georgia's economy. Agribusiness would supply more inputs to farmers and process and handle more agricultural products. In addition, farmers and agribusiness workers, as consumers, would purchase goods and services from numerous sectors of the economy. Assuming that this increased level of production and farm income would be sustained, aggregate personal income would increase $9.1 million annually.

The new cropland placed in production in 1973-1976 represents only a small fraction of total marginal, submarginal, and Soil Bank land that could be placed in crop production in Georgia in the future. Over 5 million hectares of marginal and submarginal land in Georgia has a potential for crop production. Land identified as having a potential for crop production excludes very steep and stony land but includes land that may require some conservation measures before it could be placed in crop production. The Piedmont, Southern Coastal Plain, and Atlantic Coast Flatwoods each contain over 1 million hectares of this land. However, the other LRAs also contain substantial acreages of marginal and submarginal land that could be used for crop production.

Most of the Soil Bank land that had not been placed in crop production by 1976 remained in trees. It was estimated, however, that from 12.5 to 14.5 percent of the acreage in pine plantations on Soil Bank land had been cleared by 1976. Because trees on Soil Bank land are reaching sawtimber size and are producing $74 worth of wood (using 1976 prices) per hectare per year on the average, little of this land is expected to be cleared in the near future. In the long-run, trees on this land will be harvested, and if crop prices are favorable this land could eventually be placed in crop production.

SECTION 3

METHODOLOGY

The methodology developed in this study to estimate ex post environmental and economic impacts of land use changes is presented and evaluated in this section. For ease in exposition, the methodology can be segmented into several major components as shown in Figure 1. The first segment deals with inventory of land resources within the area under consideration. In this segment, basic soil resources and their potential capability for agricultural use are defined. Marginal, submarginal, and Soil Bank land are also defined. The first segment is primarily descriptive but provides concepts utilized in later analysis.

The first analytical component involves estimation of land use changes. Both the magnitude and the form of changes, as well as identification of soil resources on which the land use changes occurred, are considered in this component. The next component involves estimation of changes in agricultural input use associated with changes in land use from pasture and forestry to crops. Here emphasis is placed on fertilizer and pesticide use, both of which are important in considering environmental as well as economic impacts. The final two methodological components involve estimation of the environmental and economic impacts of land use and associated input changes. Environmental impacts considered include loadings of sediment, nitrogen, phosphorus, and pesticides. The economic impacts focus on two components: (1) changes in farm income, and (2) the impact of changes in farm inputs and income on other sections of the economy. Estimation of the external (i.e., societal) costs of changes in environmental loadings was beyond the scope of this study. The nature of these costs and problems associated with their measurement, however, are summarized in the economic impact section.

LAND RESOURCE INVENTORY

The methodology used in inventorying land resources is summarized in Figure 2. The most aggregate level is Land Resource Regions. The continental United States is divided into 20 Land Resource Regions, based primarily on land uses within each region. Each region is subdivided into Land Resource Areas (LRAs), which are more representative of general classes of soil found within each Resource Region. Much of the information in this report was collected at the county level and compiled by LRA. Estimation of the environmental and economic impacts associated with land use configurations and land use changes requires more detailed knowledge of certain chemical and physical properties related to individual soil series or groups of soil series called associations.

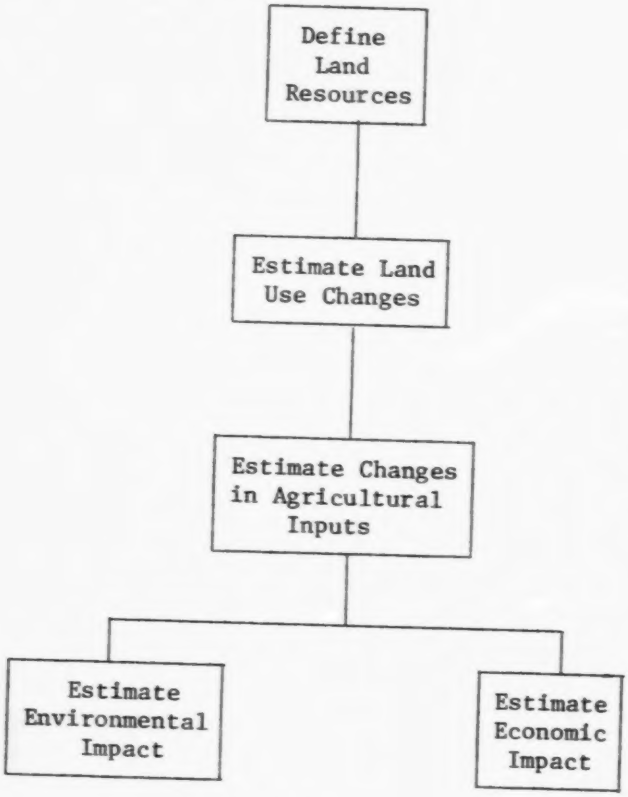

Define Land Resources
Estimate Land Use Changes
Estimate Changes in Agricultural Inputs
Estimate Environmental Impact
Estimate Economic Impact

Figure 1. Overview of methodology.

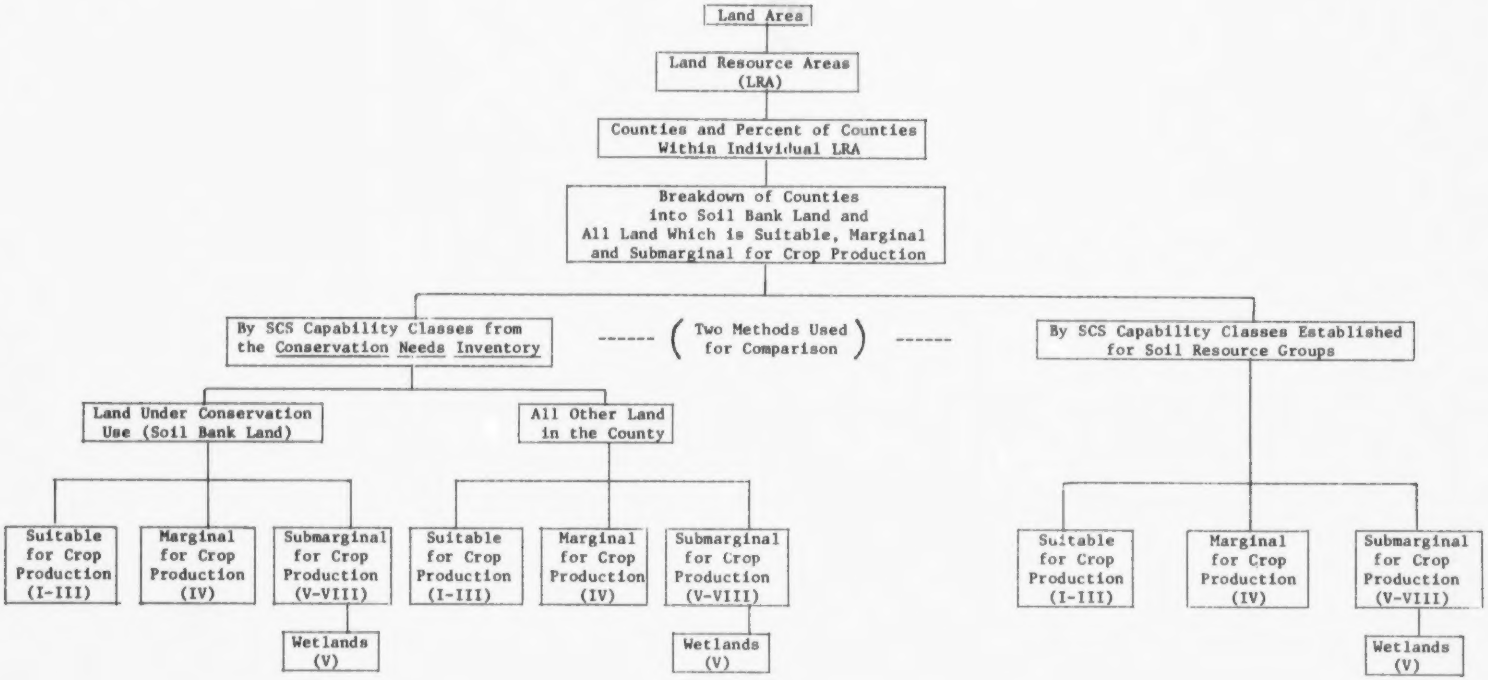

Land Area
Land Resource Areas (LRA)
Counties and Percent of Counties Within Individual LRA
Breakdown of Counties into Soil Bank Land and All Land Which is Suitable, Marginal and Submarginal for Crop Production
By SCS Capability Classes from the Conservation Needs Inventory
------ (Two Methods Used for Comparison) ------
By SCS Capability Classes Established for Soil Resource Groups
Land Under Conservation Use (Soil Bank Land)
All Other Land in the County
Suitable for Crop Production (I-III)
Marginal for Crop Production (IV)
Submarginal for Crop Production (V-VIII)
Wetlands (V)
Suitable for Crop Production (I-III)
Marginal for Crop Production (IV)
Submarginal for Crop Production (V-VIII)
Wetlands (V)
Suitable for Crop Production (I-III)
Marginal for Crop Production (IV)
Submarginal for Crop Production (V-VIII)
Wetlands (V)

Figure 2. Schematic showing how land resources were inventoried.

Areas representing soil association were planimetered from a soil association map. First, individual county areas were planimetered. Then soil associations within each county were planimetered. Planimetering was judged to be at least 98 percent accurate when comparing derived county land areas with other sources. These data were used to calculate the area of various soil associations within each county. Slope ranges were obtained from the soil association map, which included ranges of 0-5%, 5-12%, 12-25%, 25-60%, and >60%. The most dominant soil series found within each soil association was used to establish Soil Resource Groups (SRGs). Soil associations were given the same name as the dominant soil series and were considered to have properties similar to that series. Different associations dominated by the same series were given the same SRG name. Some SRGs may have the same general name, but are different because of their slope. It should be noted that grouping soil series together and assigning the characteristics of the dominant soil series to the entire group is an oversimplification that may bias the results. The degree of bias is an empirical question that will be considered in the empirical section of this report. Disaggregating the analysis to the soil series level would have greatly compounded the amount of soils data and would have increased problems in establishing correspondence of soils data to other secondary county data.

To estimate chemical and sediment loadings, each SRG was characterized by those physical properties important in calculating erosion and runoff. Dominant agricultural production capability classes and subclasses were established for each SRG, based on the average slope associated with dominant soil series.

Marginal and submarginal lands, as used in this study, are based on the Soil Conservation Service system of land capability classification. Under this system, land is classified according to its ability to produce cultivated crops and pasture without deterioration over a long period of time (Hockensmith, 1948). The capability system groups soils by common management problems. Classes I-III are classified as suitable for cultivation. Class IV is marginal, Class V is wetlands, and Classes VI-VIII are submarginal for crop production. Classes V-VIII are grouped and classified as submarginal lands for purposes of this study.

The land area in each county classified as suitable for cultivation, marginal, and submarginal for crop production, as established for SRGs, were compared (see Figure 2) with published data on capability classes reported in the Conservation Needs Inventory, 1967 (U. S. Department of Agriculture, Soil Conservation Service, 1970). This comparison provides some measure of accuracy of the approach used in this report.

The Soil Bank program was established by the Agricultural Act of 1956 in an attempt to reduce agricultural production and thus bring production in line with utilization (U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, Farm Commodity and Related Programs, 1976). This Act contained two principal provisions: (1) under the Acreage Reserve provision, farmers were paid to reduce planted acreage of allotment crops. The Acreage Reserve was operated under annual agreements with producers for three years; and (2) under the Conservation Reserve provision, farmers were paid to divert all or part of their cropland to soil-conserving uses under long-term contracts. The Conservation Reserve Program was a general cropland retirement program.

To participate in the CRP farmers contracted to withdraw a designated area for a period of three to ten years. A conservation cover (trees or grasses) had to be maintained on the diverted land. In addition, each participant's cropland acreage had to be reduced by the amount of acreage placed in the CRP. For participating in the program, farmers received an annual rental payment to compensate for the loss of income that the acreage otherwise would have produced.

The CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970) was used to identify Conservation Reserve acreage by soil capability classes and subclasses. That publication reported acreage of land under the heading of "conservation use only" in 1967. Although this category has a broader definition than Conservation Reserve, a majority of the acreage was Conservation Reserve acreage. The acreage restricted to "conservation use only" will be referred to in subsequent sections of this report under the general term of Soil Bank land.

One of three alternative units of analysis could have been used in the study--hydrologic units, water quality management units, or political units. Hydrologic units, which designate drainage areas with all water in the area draining to a selected point, could have been the primary unit for analysis. A second alternative could have been the selection of water quality management units, which are generally bounded by rivers or smaller streams and ridge tops. Finally, political units such as counties or planning areas could be used as the unit of analysis. Soils data can be planimetered on the basis of any of these units. Secondary sources of land use are available for counties but not for hydrologic or water quality management units. Economic data related to agricultural production and input usage would only be available at the county level. Also, data on land in the Soil Bank are available only at the county level.

Land was classified in this study according to its ability to produce crops and pasture. This avoids the very serious difficulties in defining land types that have recently arisen in the national debate on prime agricultural lands (U.S. Department of Agriculture, Perspectives on Prime Lands, 1975). Preservation of prime agricultural lands has been a popular cry, but the scientific community has been unable to clearly delineate criteria to define prime agricultural land. The problem is complicated by the fact that an appropriate classification system for prime agricultural land would have to include technical, aesthetic, economic, environmental, and social variables.

The approach used relies on soil classification criteria developed by soil scientists. The advantages of this approach are twofold. First, the classification system is well understood because it is widely used. Secondly, land resources in most states have already been classified with this system in the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970). Any other approach involving a complete inventory of the state's land resources would be beyond the scope of this study.

LAND USE CHANGES

The overall process for estimating land use changes is shown in Figure 3. Land use changes are calculated at the county level and aggregated for LRAs and for the state as a whole. Net additions to crop acreage for the period 1973-1976 were determined from annual estimates by the Economics, Statistics, and Cooperatives Service (Georgia Agricultural Facts, 1978). Although total crop acreage in each county is not reported directly, it can be estimated using acreages of the major crops. Only those counties that experienced an increase in crop acreage during 1973-1976 were assumed to bring new cropland into production. Some new cropland may have been brought into production in other counties, but such counties would experience no net addition to crop acreage.

Increased crop acreage may involve the conversion of several land-use patterns to crop production. For example, woodland, pasture, wildlife areas, idle lands, or wetlands may be converted to crops. Woodland and pasture are particularly important for economic considerations because these lands generate marketable products and farm income that must be foregone to produce crops. Surveys conducted by the Soil Conservation Service and Cooperative Extension Service were used to identify types of land use conversion to crop production in each county.

Having determined general row crop changes for each county, the next step involved relating crop changes to specific soil series or soil associations. Two approaches were used to identify increases in crop acreage by SRG. LANDSAT remote sensing technology was used in the first approach. LANDSAT scenes that contained a large portion of agricultural land were chosen for analysis. A sample of counties within each of the scenes was identified on the basis of soils and crops as representative of the particular LRAs. Land use changes within a county were superimposed on county soil maps in order to quantify land use changes according to SRGs. A more detailed description of the LANDSAT procedure is presented in Appendix A.

The second approach used to link cropland changes with SRGs relied on the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970). New cropland was assumed to be distributed among the classifications of suitable, marginal, and submarginal land in the same proportions as land already in cultivation as reported in the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970). Within the classifications of suitable, marginal, and submarginal land for cultivation, new cropland was allocated to the various SRGs in proportion to their relative shares of the land area. For example, if suitable (Class I-III) land in a county was in two SRGs with the same number of acres then new cropland on this land was assumed to be equally distributed between these two SRGs.

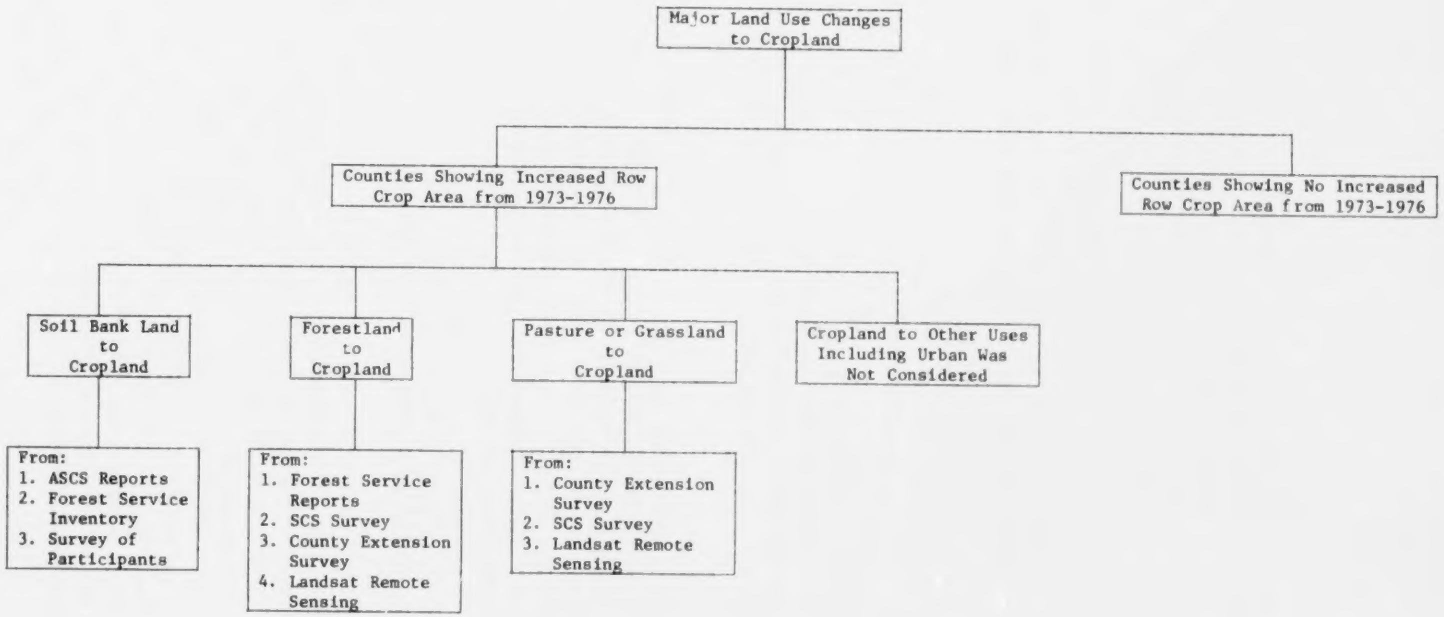

Major Land Use Changes to Cropland
Counties Showing Increased Row Crop Area from 1973-1976
Counties Showing No Increased Row Crop Area from 1973-1976
Soil Bank Land to Cropland
Forestland to Cropland
Pasture or Grassland to Cropland
Cropland to Other Uses Including Urban Was Not Considered
From: 1. ASCS Reports 2. Forest Service Inventory 3. Survey of Participants
From: 1. Forest Service Reports 2. SCS Survey 3. County Extension Survey 4. Landsat Remote Sensing
From: 1. County Extension Survey 2. SCS Survey 3. Landsat Remote Sensing

Figure 3. Schematic showing identification of land use changes.

The economic theory of land use provides a basis for assessing some of the methodological assumptions utilized in this study. The neoclassical theory of land use suggests that landowners select the appropriate use for land on the basis of the sum of discounted future net revenues from alternative land uses (Barlowe, 1978; Alonso, 1964). From this viewpoint, land would shift from pasture and forestry to cropland whenever the perceived sum of discounted future returns from crops became greater than from other uses. This basic hypothesis has some important implications for the methodology in this study. First, one would not necessarily expect all land of similar quality to be shifted at the same time. Because these decisions are based on the subjective expectations of future revenues, the expectations of different landowners would likely be different. In addition, the stage of maturity of the timber on some of the forestland may provide incentives for delayed harvesting. Secondly, shifts in land use would not necessarily be limited to one type or quality of land. Although land more suitable for cultivation might have higher returns from crop production than marginal or submarginal land, increased crop acreage would not be limited to this classification of land. Marginal and submarginal lands may have higher returns in crop production than in other uses. Landowners, therefore, would also shift some marginal and submarginal land into crop production if they have expectations that crop production is more profitable than other uses.

The first methodological approach discussed in this section of using survey information to determine the land use patterns would be the preferable approach. In the absence of sufficient resources to support a large scale empirical study, however, the second approach does have merit. Basing the proportion of new crop land that is suitable, marginal, and submarginal on historical proportions takes into consideration previous economic decisions related to appropriate land use. This approach requires the assumption that land use changes were based on similar economic calculations as those associated with historical patterns. Although this assumption can be questioned, it does have an empirical basis. Research to validate this assumption would be useful, but without these data the second approach utilized here can be used in land use and environmental research.

CONVERSION OF SOIL BANK LAND

Most of the land that was placed in the CRP (Soil Bank program) was previously used for crops, hay or pasture. Hence, it was hypothesized that a significant portion of this land would be converted from conserving uses to crops in the 1973-1976 period. Determination of the status of this land was based on surveys of participants in the Soil Bank program. The list of Soil Bank participants was stratified by geographic areas of the state to assure that selected samples would be geographically representative. Then 10 percent of the participants in each stratum were randomly selected and surveyed through mail questionnaires. A follow-up questionnaire was sent to ensure adequate response.

INPUT USAGE

The type and quantity of inputs was estimated for cropland being brought into production. The use of chemical fertilizers and pesticides is of primary importance because these inputs may adversely affect public water supplies, recreation opportunities, as well as contribute to the cost of crop production and, therefore, may result in both direct and off-site economic impacts. Two methodological problems are involved in estimating chemical input use. The first problem involves the paucity of secondary data for quantities of agricultural inputs. Unlike crop acreages and production estimates, chemical use is not routinely derived. The problem is especially acute for pesticides, for which the only general source of information is periodic surveys by the U.S. Department of Agriculture.

The second problem involves obtaining sufficiently disaggregated data on input use. Many secondary input use data are state estimates, and, in the case of pesticides, the data are for multistate regions. For this study the problem was crucial, because economic theory would lead one to expect that input use would vary spatially, especially among SRGs. Because the marginal productivity of an input could vary among different SRGs, the amount of input used would likely vary. This proposition has special validity for fertilizer use, where differences in natural fertility and capacity of the soil to retain fertilizer nutrients throughout the production season would lead to different crop responses from fertilizer. In similar manner, differences in soil and climate among different regions could lead to differences in incidence of weeds, insects, and fungi so that the productivity of pesticides could also vary.

These economic hypotheses suggest that the appropriate data for estimation of input use would have to be collected through surveys of the area under consideration. If county data on input use are unavailable, an alternative approach would be to apply regression analysis to estimate use on particular soil groups that are larger than counties. According to Ziemer, Musser, and Clifton (1978), this approach involves estimating the following equation using dummy variables.

$$I_{ij} = \sum_{k} a_k D_{ik} + \sum_{i} a_l Y_{il} + \sum_{m} a_m D_{ik} Y_{il} \qquad (1)$$

where I_{ij} is the quantity of the jth input in the ith county; D_{ik} is a dummy variable for different soil groups; Y_{il} is acreage of the lth crop in the ith county; and a_k, a_l, and a_m are regression coefficients. For a particular crop, Y_l, on a particular soil, D_k, the amount of use of an input, I, per hectare would be equal to $a_k + a_l + a_m$. In their empirical application of this approach, Ziemer, Musser, and Clifton (1978) were unable to find a statistically significant effect of soil group on the amount of input used.

County data on fertilizer sales are available; however, it appears that sales data are not a good proxy for use data. Problems with sales data other than normal questions of reliability, include the possible use in counties outside the sales area and actual use in years other than purchase year. A third approach is to utilize the expert knowledge of researchers and extension personnel in the area under consideration to synthesize estimates of input use. With sufficient breadth of specialized experience, it would be possible to synthesize estimates for various soil provinces or other subregions under consideration. This methodology has been extensively used in production economics and farm management research as well as in previously referenced economic studies of agriculture related nonpoint pollution.

Because of limited data, the third approach was utilized in this study. . Use data were developed for each crop and for the state as a whole. State rather than substate data were used for two reasons. First, previous research with aggregated input data indicates no significant differences in input use among provinces in the state (Ziemer, Musser and Clifton, 1978); and second, there is a lack of sufficient expertise to synthesize substate estimates. These estimates were designed to be representative of use rates for all levels of management in the state. For fertilizer inputs, previously synthesized estimates were modified and reviewed by personnel in the Georgia Cooperative Extension Service and the Economics, Statistics, and Cooperatives Service, USDA.

For pesticides, representative use rates were not available on a state level for the period of analysis. The procedure used to estimate pesticide use involved updating the Pesticide and General Farm Survey that was conducted in 1971 (USDA, Economic Research Service, 1971). Lists of chemicals identified in that survey along with amounts used per hectare in 1971 were sent to state specialists in the Cooperative Extension Service to estimate the type and amount of chemicals used in 1976. These specialists were asked to estimate amounts and levels of chemicals in use in 1976 that would have replaced chemicals no longer used.

ENVIRONMENTAL IMPACTS

The nonpoint agricultural pollutants of primary concern are sediment, nitrogen, phosphorus, and pesticides. Pesticides, fertilizer, and sediment are delivered to water bodies primarily by water runoff. Runoff transports dissolved water-soluble chemicals, as well as chemicals bonded to sediment particles. Runoff can originate from both rainfall and irrigation; however in this study, the analysis focused on rainfall. Figure 4 shows factors that were considered in evaluating the environmental impact associated with increased crop acreage.

Sediment

Sediment affects the quality of water resources directly but also may carry pesticides and plant nutrients adsorbed on the soil particles. The contribution of agricultural land to sediment in waterbodies is dependent primarily on the erosion rate and the sediment delivery ratio, i.e. the proportion of eroded soil that reaches the stream. Using representative soil, cover, and topographic features, it is possible to estimate the erosion rate for relatively homogeneous agricultural areas.

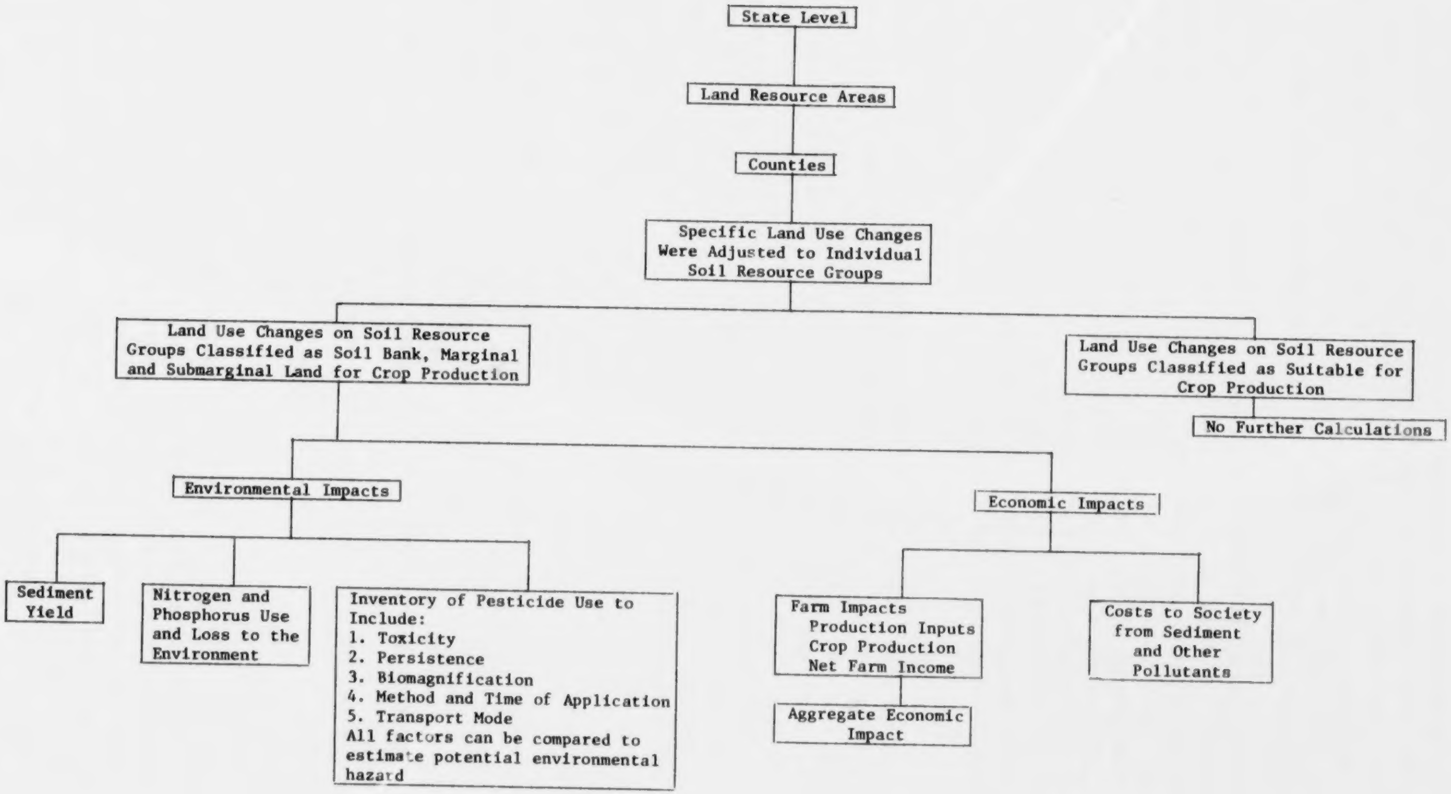

State Level
Land Resource Areas
Counties
Specific Land Use Changes Were Adjusted to Individual Soil Resource Groups
Land Use Changes on Soil Resource Groups Classified as Soil Bank, Marginal and Submarginal Land for Crop Production
Land Use Changes on Soil Resource Groups Classified as Suitable for Crop Production
No Further Calculations
Environmental Impacts
Economic Impacts
Sediment Yield
Nitrogen and Phosphorus Use and Loss to the Environment
Inventory of Pesticide Use to Include:
1. Toxicity
2. Persistence
3. Biomagnification
4. Method and Time of Application
5. Transport Mode
All factors can be compared to estimate potential environmental hazard
Farm Impacts
Production Inputs
Crop Production
Net Farm Income
Aggregate Economic Impact
Costs to Society from Sediment and Other Pollutants

Figure 4. Schematic showing evaluation of economic and environmental impacts associated with increased cropland.

Sediment yield per hectare of agricultural land, which depends on estimation of potential soil loss utilizing the Universal Soil Loss Equation (Wischmeier and Smith, 1965) and sediment delivery ratio, may be expressed as:

$$SY = (R \cdot K \cdot L \cdot S \cdot C \cdot P)\, S_d \qquad (2)$$

where

SY is sediment yield from surface erosion in tons per hectare

R is the rainfall and erosivity index

K is the soil-erodibility factor which depends on soil properties

L is the slope length

S is the slope steepness

C is the cover and management factor

P is erosion control factor, with no control $P = 1.0$

S_d is the sediment delivery ratio.

The factors R, K, L, and S, which are fixed for a given location under existing management, determine the location's characteristic erosion potential. Factors C and P, on the other hand, are determined by management. The cover and management factor C is related to the soil's ability to resist erosive forces as affected by vegetation cover, crop sequence, management, and agronomic erosion control factors. Factor P concerns such cultural practices as contour plowing and terracing.

Soil topographic details such as soil properties, slope steepness, and slope lengths were determined for each SRG in the state. Soil survey maps from the Soil Conservation Service were the primary sources for soil characteristics and associated land features. These maps included classifications of erosion potential and land slope. Land slope class indicates whether the land is nearly level (0-5 percent slope), gently sloping (5-12 percent), moderately sloping (12-25 percent), strongly sloping, or steep. Typical cultural practices were identified through numerous field inspections and interviews with local extension, ASCS, and SCS workers.

The amount of sediment that actually reaches a designated point such as a pond, a reservoir, or a point on a stream or river is called the sediment yield. The soil loss equation computes long-term gross sheet and rill erosion but does not directly predict downstream sediment yield. The difference in the amount eroded from a total drainage area and that transported to a selected point determines the delivery ratio. Many factors influence the sediment delivery ratio. No general equation for watershed delivery ratios has been derived, but several observed relationships provide guidelines for approximating them. Size of drainage area is an important factor, because as distance of sediment transport to downstream points increases opportunities for deposition enroute are more numerous. Sediment yield and, therefore, the delivery ratio decrease. Sediment delivery ratios vary widely for any given size of drainage area, but limited data show that, roughly, these ratios are inversely related to size of drainage area and directly related to surface texture of the more dominant soils within the watershed (Roehl, 1962).

One enigma of determining sediment delivered with this procedure is the decision of what size drainage area to use in making calculations. Obviously, the larger the stream the larger the drainage area and thus, the smaller the sediment delivery ratio. The sediment yield, therefore, can be artificially reduced by considering only larger watersheds as the appropriate drainage area. Given the state of research on estimating and assigning dollar values to social (or off-site) damages of sediment, the selection of the size of drainage area may be somewhat arbitrary. In some cases the selection will be dictated by the nature of the study (e.g., desired scale of analysis), jurisdictional boundaries (e.g., 208 planning areas), or resource planning areas. In this study, the smallest drainage areas delineated for LRAs were used. Although this methodology may overstate sediment of public concern, it was decided to give maximal rather than minimal estimates.

Runoff

Runoff, which is precipitation that appears in surface streams, occurs during and shortly after a storm. The two categories of major interest in this study are surface runoff and subsurface runoff or interflow. Surface runoff reaches the stream by traveling over land, whereas subsurface runoff infiltrates the surface soil before reaching the stream. It is practically impossible to separate surface and subsurface runoff, so these are combined for analytical purposes here and called direct runoff. For agricultural land, surface runoff is generally the major component of direct runoff, both in terms of quantity generated and pollution potential. Some areas with tile drains, for example, may be exceptions.

The amount of runoff from agricultural land must be estimated in order to measure fertilizer and pesticide losses. Surface runoff may carry fertilizers and pesticides in solution, in suspension, or adsorbed to suspended soil particles. Subsurface water can carry soluble chemicals.

The amount of runoff from agricultural land due to a storm event is related to a host of soil parameters and types of vegetation. Direct runoff is estimated here for specific storms using empirical procedures developed by the Soil Conservation Service, USDA. SRGs were assigned hydrologic characteristics of the most dominant soil series. These hydrologic characteristics influence the amount of infiltration for bare soil. The effect of land use and management practices on runoff has also been determined by the Soil Conservation Service. The effect of combined hydrologic/soil-cover characteristics on the amount of runoff is represented by a runoff curve number (CN). Potential abstraction (S), that portion of precipitation that does not contribute to direct runoff, is related to soil and cover conditions of a watershed as follows.

$$S = \frac{1,000}{CN} - 10 \quad (3)$$

Abstraction and storm rainfall are considered in measuring direct runoff as follows.

$$Q_i = \frac{(Rf_i - 0.2\ S)^2}{Rf_i + 0.8\ S} \quad (4)$$

where:

Q_i is direct runoff for ith storm event

Rf_i is total storm rainfall

S is potential abstraction

Annual potential direct runoff was based on the frequency and amount of runoff for 1, 2, 5, 10, 25, 50, and 100 year storms. Total storm rainfall (Rf_i) is measured over a 24-hour period. The expression for annual potential direct runoff is as follows.

$$AQ = \sum_{i=1}^{n} \frac{1}{Y_i} Q_i \quad (5)$$

where:

AQ is annual potential direct runoff

Q_i is direct runoff for ith storm

Y_i is 1, 2, 5, 10, 25, 50 or 100 year storm

Hence, AQ is an expected value--the sum of each runoff multiplied by the probability of that storm occurring. This formulation assumes that in any year, all of the land will receive a one-year frequency storm, half of the land will receive a two-year frequency storm, etc. Fertilizer loss is expected to be directly related to the estimate of annual potential direct runoff, but pesticide loss depends more on the distribution of direct runoff within a year.

Fertilizer Loss

Chemical fertilizers applied to cropland may reach waterbodies through leaching, runoff, and erosion. The two nutrients of environmental concern are nitrogen and phosphorus. Studies in which nitrogen and phosphorus losses from farmland were measured have found a positive correlation between land use and nitrogen and phosphorus levels in surface water (Baker, Johnson, Borcherding, and Payne, 1979; Holt, 1969; Jaworski and Hetling, 1970; and McCarl, 1971). An analysis by Omernik indicated that in the eastern United

States streams draining agricultural lands had five-fold higher total nitrogen concentrations than those from forested watersheds.

The behavior of nitrogen in a soil-plant system is complex. Fertilizer nitrogen is taken up by plants, retained in the soil organic fraction, lost by denitrification, and lost by leaching, runoff, and erosion. The Committee on Nitrate Accumulation, National Academy of Sciences estimated that 10% to 15% of fertilizer nitrogen is lost to waterways. Of this total, 49 percent is transported by erosion, 32.7 percent by leaching of native soil nitrogen, and 18 percent by transport of fertilizers by a combination of processes. Phosphorus is not lost from the soil as rapidly as nitrogen, but remains fixed and slowly becomes available for crop growth. The predominant mode of transport for phosphorus is soil erosion (McElroy, et al., 1976, pp. 102-106). Total phosphorus losses for the United States have been estimated at about 25 percent of the phosphorus made available annually in the form of fertilizer and livestock wastes (Wadleigh, 1968).

Only a limited number of scientific approaches have been used to estimate fertilizer contributions to nutrient contamination of water (National Research Council, Nitrates: An Environmental Assessment, 1978). Controlled studies of watersheds are costly, and the data provided are site-specific. Smaller-scale field experiments have limited applicability for extrapolation to larger areas. Use of tracer materials is not feasible because of the high cost.

The heterogeneity of soils and of hydrologic characteristics from site to site make general quantitative relationships for nitrogen and phosphorus losses difficult to define (National Research Council, Nitrates: An Environmental Assessment, 1978). The magnitude of losses of these two nutrients from chemical fertilizers are calculated in this study by analyzing fertilizer input usage and mode of transport to surface water. In this study it is assumed that nitrogen loss is directly linked to sediment and runoff rates through the following relationship.

$$NL_i = AN_i \left[NS \frac{SY_i}{\overline{SY}} + NR \frac{AQ_i}{\overline{AQ}} \right] \tag{6}$$

where

NL_i is nitrogen loss per hectare of cropland for ith SRG

AN_i is application rate for nitrogen for ith SRG

NS is percent of applied nitrogen lost with sediment, on the average

SY_i is sediment yield for ith SRG

$\overline{SY}$ is state average sediment yield

NR is percent of applied nitrogen lost with runoff, on the average

AQ_i is annual potential direct runoff for ith SRG

$\overline{AQ}$ is state average potential direct runoff

According to this relationship, nitrogen loss due to erosion on land with potential sediment yield that differed from the state average would differ proportionately from the average amount linked to erosion. Also, nitrogen loss on land with a potential runoff rate that differed from the state average would differ proportionately from the average amount linked to runoff. Using a similar procedure, phosphorus loss is directly linked in this study to the fertilizer application rate and sediment as the predominant transport mode.

$$PL_i = AP_i \ [PS \frac{SY_i}{\overline{SY}}] \qquad (7)$$

where

PL_i is phosphorus loss per hectare of cropland for ith SRG

AP_i is application rate for phosphorus for ith SRG

PS is percent of applied phosphorus lost with sediment, on the average

SY_i is sediment yield for ith SRG

$\overline{SY}$ is state average sediment yield

Phosphorus loss on a particular SRG for a given application rate would differ from the state average in relation to the sediment yield.

Pesticide Loss

Use of chemical pesticides (insecticides, fungicides, and herbicides) in agriculture results in the possibility of harmful impact on environmental quality (U.S. Department of Agriculture, Agricultural Research Service, Control of Water Pollution from Cropland, 1976). Problems with pesticides occur when they move away from the site of application but continue to affect the environment. Pesticides move from treated fields primarily in runoff water or on sediment carried along in the water. In this study areas of potential pollution problems resulting from the movement of pesticides off treated cropland are explored.

Pesticides differ widely in their chemical properties, toxicity, and mode of transport. These characteristics have been identified in previous studies and are summarized in Leonard, Bailey, and Swank. Properties affecting pesticide behavior in soils include solubility, extent of adsorption, and vapor pressure. The solubility of a pesticide determines how rapidly the compound moves in water. Adsorption, which is the extent of attraction between soil and pesticides in this case, controls the quantity of a pesticide in soil solution and soil vapor. Hence, adsorption determines such factors as pesticide mobility, mode of transport, degradation, and volatility. For example, movement of pesticides that are adsorbed on soil colloids is highly dependent on the rate of soil loss or erosion. Pesticide vapor pressure determines potential volatility from soils.

In identifying potential pesticide pollution problems, toxicity and biomagnification must be taken into consideration. Because this study focuses on water quality, the only form of toxicity to be considered is toxicity in the aquatic environment. Hence, toxicity is measured by the amount of pesticides required to kill fish in a specified period of time. Some pesticides can accumulate or be magnified in the biological food chain. Biomagnification occurs when some organism accumulates a pesticide in body tissues many times that in the surrounding environment (Kenaga, 1975).

The length of time that a pesticide can persist in the soil and aquatic environment varies widely from one pesticide to the next. Persistence, however, depends on degradation, adsorption, movement and transport of the chemical pesticide. Pesticide degradation or decomposition can be accomplished by microbial as well as nonbiological processes (Armstrong and Konrad, 1974; Crosby, 1970; and Kaufman, 1974).

Factors concerning application of pesticides must also be taken into consideration in identifying potential pollution problems. The quantity of pesticides moving into water obviously depends on the amount of pesticides initially applied. Both the application rate per acre and the number of acres treated affect the quantity of pesticide loss. Because the quantity of a pesticide moving into water depends on the intensity and duration of rainfall, the timing of application is important. Those pesticides applied during rainy seasons would have a greater potential for pollution problems. Pesticide losses are generally highest in the first runoff occurring after application of the pesticide, and the magnitude of the loss decreases as time between application and runoff increases (U.S. Department of Agriculture, Agricultural Research Service, Control of Water Pollution from Cropland, 1976). The mode of application affects pesticide loss. For example, soil-incorporated pesticides will not be lost in runoff to as great an extent as pesticides sprayed on foliage.

The approach used in this study has two components: (1) How harmful is the pesticide?, and (2) How much of the pesticide can potentially move from applied sites to harm environmental quality? Both of these components cannot be analyzed as simply as other pollutants from agriculture. In the first place, a large number of pesticides are utilized in agricultural production. Furthermore, several dimensions of the first component have environmental relevance - toxicity, persistence, and biomagnification. These dimensions combined with the number of pesticides result in a large amount of data on pesticide use. If the results of the analysis are to be useful for policy makers concerned with changes in land use, these data must be condensed--yet in a manner that maintains their environmental relevance.

Analysis of the first component is complicated due to the fact that prior research on the processes of pesticide movement in the environment is lacking. For the analysis in this study, no standard loading function analogous to functions for sediment, nitrogen, and phosphorus was available for pesticides.

Each of these problems required special attention in development of methodology.

Previous researchers have developed indices to study the harmful impact of various pesticides in the environment. Klaus Alt reviewed two such indices before developing one for his study. One index was defined as follows.

$$PEH = M \times L \times T \times B \qquad (8)$$

where PEH = potential environmental hazard, M = mobility of the pesticide, L = longevity of life, T = toxicity to fish, and B = biomagnification. Each of these factors are given an ordinal rating to construct an index. An alternative index that is specific to management of a specific crop rather than a particular pesticide is:

$$I = \sum_j \frac{A_j}{d_j \times LD_j} \qquad (9)$$

where I = value of the index, A_j = amount of pesticide j used, d_j = decomposition rate of the pesticide j, and LD_j = lethal dose of pesticide j to test animals. Alt adapted these indices in his analysis to the following form.

$$EEI = \sum_i \frac{h_i \times A_i}{\ln 2 \times LD_i} \qquad (10)$$

where EEI = environmental exposure index, h_i = half-life in years of pesticide i, A_i = periodic application rate of pesticide i, ln 2 = natural log of 2, and LD_i = lethal dose of pesticide i to rats.

The limited number of crops and management systems considered in this study precluded the necessity to develop aggregate indices. The index chosen could be specific to particular pesticides. In addition, the use of toxicity to fish as used in the first index was judged to be more relevant for nonpoint source water pollution concerns. The application rate factor in the second and third indices, however, appeared to be a useful addition; the amount of pesticide applied is a relevant factor in judging its potential harm. With these considerations the index used in this study is:

$$I_j = A_j \times T_j \times P_j \qquad (11)$$

where A = quantity applied per hectare, T = toxicity to fish, and P = persistence in soil. Each of these three factors is given a qualitative rating, based on secondary data--A and T have values of 1, 2, 3 and P has values of 1, 2, 3, or 4. The pesticides are then ranked on the basis of their I_j values into four categories of potential impact. (Details of the quality ratings for the factors and overall impact are presented in the empirical section.)

As with all indices, some information on the potential environmental harm of pesticides is lost in the construction of indices. It was judged, however, that some condensation of information was necessary for meaningful policy decisions. Without such condensation, decision-makers would be overwhelmed with the quantity of technical data. If more details concerning a specific pesticide are desired in the decision process, such information could be developed with the information provided by this methodology.

Methodology for consideration of the second component of the analysis of pesticides (i.e., their potential movement) was even less satisfactorily developed in the literature. The loading functions for pesticides presented by McElroy and coworkers were not satisfactory for this study. These funcions consider concentration of pesticide in the soil to be an important factor. Calculation of this concentration requires knowledge of both the initial concentration and the impact of pesticide applications on concentration. Limited secondary information exists on both these parameters. Particularly limiting was information on initial concentration of pesticides on land recently converted to cropland. In fact, McElroy and coworkers recommended development of site specific data on concentration. Because sample collection and laboratory analysis were beyond the scope of this study, the actual loadings of pesticides could not be estimated. An alternative approach was to present potential loadings. This approach was based on presentation of estimates of quantities of pesticides applied, summarized with the index presented earlier in this subsection for different provinces of the state. In addition, qualitative information was considered in reference to mode and time of application, factors that do influence potential pesticide loadings.

One of the major factors found to directly influence the total amount of pesticide lost, and the resultant concentration in runoff and sediment, is the proximity of runoff-producing rainfall to the application date. Characteristically, pesticide losses are highest in the first runoff occurring after application of the chemical, and the magnitude of the loss generally decreases as time between application and runoff increases. The effect of time is particularly noticeable for short-lived pesticides and for pesticides that are not incorporated into the soil. Concentrations of chemicals in subsequent runoff events decrease at a rate that depends largely on the persistence of the pesticide in the soil. Normal planting date for selected crops, mode and time of pesticide application, and monthly percipitation and river flow data can be used along with pesticide characteristics to evaluate the potential movement of pesticides away from site of application.

ECONOMIC IMPACTS

The methodologies used to estimate the economic benefits and costs associated with increased crop production are described in this section. Economic factors to be considered are discussed in Figure 4. The most obvious beneits are increased farm sales and net farm income. In addition, the aggregate economy benefits as a result of the larger volume of farming inputs purchased from the nonfarm sector and the larger volume of farm products being processed and handled by agribusiness firms. On the other hand, however, social costs associated with increased crop production occur as increased quantities of fertilizers, pesticides, and sediment are released to the environment.

Net Farm Income

This component of the methodology provides measures of both the positive and negative impacts on profits of changing agricultural land use. To determine the net increase in profits on land taken out of forest or pasture to be placed in crop production, the opportunity costs associated with foregone profits from production of timber or pasture products must be taken into consideration. Therefore, estimates of net income per hectare for crops, forest, and pasture are accounted for in the methodology.

Enterprise budgets were developed for major crops produced on new cropland. This approach would exclude crops with acreages limited by government programs and emphasize feed grains and soybeans, which increased during the 1973-1976 period in response to expanded export demand.

Budgeted costs included expenditures for seed, labor, fertilizer, lime, chemicals, tractors, machinery (fuel, lubricants, and repairs), interest, and custom operations. Costs were based on the average use of inputs and average annual prices. For example, the fertilizer use per hectare was multiplied by its price to determine the fertilizer cost. Estimated variable costs for tractor and machinery items were based on average use to till and harvest one hectare of the specified crop. Interest on operating capital was charged at nine percent for the length of the production period. The operating capital was assumed to be borrowed only for the length of time necessary to secure inputs in a timely fashion. The actual loan for the money was assumed to be closed before the production period began. Several factors, including combining, hauling and storage, are related to crop yields.

Crop yields in each county were calculated for every SRG producing crops. Two sources of information were used: (1) potential yields for each SRG as reported by the Soil Conservation Service (U.S. Department of Agriculture, Soil Conservation Service, Compilation of Soils Data in Georgia, 1972); and (2) county average yield as reported by the Economics, Statistics, and Cooperatives Service (U. S. Department of Agriculture, Statistical Reporting Service, Agricultural Prices, 1977).

These budgeting procedures embodied several assumptions that seemed reasonable for the situation in this study. First, the use of average annual prices for outputs and inputs is appropriate only if the changes in these quantities were small enough that they would not affect price. Given that the acreages of concern in this study were small relative to existing state acreages, which are also small relative to national totals, this assumption seemed reasonable. In situations in which the acreage of concern was larger relative to aggregate levels, changes in consumer and producer surpluses would need to be calculated rather than changes in net farm income (Eckstein, 1958; Currie, Murphy, and Schmitz, 1971). These surpluses measure the value of increased agricultural production to consumers and producers, respectively.

The second assumption is that fixed costs need not be considered in the analysis. Given that small acreages are involved, it was assumed that existing machinery and management were sufficient for the incremental cropland.

With the well known overinvestment in farm machinery, this assumption is reasonable if the new cropland is being added to existing farm firms. If the new cropland served as the basis for new farm firms, investment in machinery would have been necessary and the fixed costs of machinery would have to have been considered in the analysis. Primary data from farm surveys could be used to validate this assumption.

Procedures for estimating net revenues from forestry and pasture could not be based on existing enterprise budgets. In the case of forestry, the existing state of knowledge on farm forestry enterprises in the area of study is nearly void. This statement refers to both existing enterprise budgets and secondary data on yields and prices. Differences in tree species throughout the area of study combined with differences in management precluded any systematic development of budgets for this study.

The source of data utilized to estimate net returns from forestry was county estimates of gross farm income from forestry sales in the 1974 Census of Agriculture (U.S. Department of Commerce, 1977). From these data, it was possible to derive gross income per hectare of farm forestland in each county. Because specialized equipment is used for most forestry harvest, it was reasonable to assume that this income reflected only stumpage prices; thus, no harvesting costs would have to be deducted from the gross sales. Furthermore, the establishment and maintenance costs of farm forests can be assumed to be zero because of the low maintenance costs. Under these assumptions, the gross sales could be considered net income from forestry for 1974. Under the further assumption that 1974 was representative of sales levels in the period of analysis, these sales data could be considered representative of net revenue from forestry. These methods probably overstated the net revenues from farm forestry.

The problem with estimation of net revenues from pasture was different from forestry in that past agricultural economics research has emphasized pasture budgets (Wise, 1974). The pasture enterprise in this research, however, is an intermediate product in beef production. Adopting past research would have necessitated also considering beef enterprises. The problem with beef enterprise budgeting would have been determination of the representative beef enterprises. A large number of different beef enterprises - cow-calf, stocker cattle, backgrounding calves, and fattening cattle - combined with a large variance in use of pastures along with other feed in beef enterprises makes this a difficult process without considerable primary data. Furthermore, historical studies of the structure of beef cattle enterprises have doubtful validity in this study period because of the adjustment of beef producers to the low cattle prices during this period. The approach for estimation of net revenues from pasture therefore was based on secondary data on cash rents for pasture that is available for Crop Reporting Districts (USDA, ESCS, "Cash Rents," 1976). Even if the pasture was not rented, these cash rents do define opportunity costs for pasture use. In this study, it was assumed that all variable costs associated with pasture use such as fence repairs, fertilizer, and weed control were assumed by the renter. Prorated fixed costs for fencing, however, was deducted from the cash rents to determine net revenue from pasture. The fencing costs were estimated for a 16.2 hectare rectangular pasture.

As in the methodology for estimating net income from other land uses, the determination of validity of these assumptions would require primary data.

Impact on the State's Economy

Shifts in agricultural production and farm income affect not only farmers but also income and employment in agribusiness firms that process and handle agricultural products and supply inputs to farming. The effects of these changes, however, do not stop here, as agribusiness firms purchase from other industries and workers in agriculture and agribusiness spend their money for goods and services produced by other industries.

Analytical procedures to quantify the interindustry flows between agriculture and nonfarm sectors are complex and expensive to use. Input-output analysis, for example, requires a great deal of primary data that must be generated through surveys. Also, current techniques are focused on the many sectors of the nonfarm sector. This level of disaggregation in the nonfarm sector is not needed to measure the impact of agriculture on the state's economy. A major limitation of techniques currently used to measure interindustry flows is that they measure average effects rather than marginal effects. Thus an alternative approach is needed to measure the marginal effect of changes in agricultural production, which is more useful than average effects for guiding investment decisions.

Adequate secondary data are available for state and sub-state economies to quantify the effect of a change in agricultural production on important economic variables. An econometric model of interindustry economic flows was developed for state economies. Attention was focused on the role of the agricultural sector in the overall economy. Realizing that modeling economic systems is enormously complex, primary concern was devoted to identifying and quantifying the principal economic characteristics of the economy. Methodological development and estimation of this model is reported in Appendix B.

The impact on the state's economy of the changes in agricultural output identified in this report was assessed by using the interindustry model presented in Appendix B. Land changes in production have resulted in increased input usage, agricultural production, and net farm income. Each of these factors was estimated and entered into a simulator based on the economic interindustry model. The simulation model used the estimated farming variables by linking the agricultural and nonagricultural sectors through a set of economic flows. The impact of changes that have occurred in agricultural production was traced through the economic system by observing changes in these flows.

Environmental Costs

This section addresses the potential social costs that may result from converting forest and pasture land to crop production. In recognition of these social costs, this section discusses the impact of nonpoint source pollutant loads on water quality and resultant impacts on water uses. The section also provides a general discussion of the nature of these environmental costs and of the problems of measuring and assigning a value to such costs.

Pesticides, fertilizers, and sediment are the primary substances resulting from increased crop production that have an impact on water quality. Although the quantity of sediment is not appreciably reduced in the receiving water, pesticides and fertilizers are reduced by the biological, physical, and chemical processes that occur in water. Sediment can cause turbidity in surface waters, which makes the water less attractive and can damage fish life (Kneese and Bower, 1968). Turbidity may also inhibit the growth of algae and other aquatic plants. Increased fertilizer loadings may aggrevate the pollution problems for water bodies that are susceptible to eutrophication (nutrient buildup). Thus, nutrient and sediment loss from agriculture can have visible effects on water quality. These take the form of algae blooms, murky or shallow water, and dense weed growth (Ogg, Christensen, and Heimlich, 1979). Pesticides may lead to destruction of wildlife and may involve health hazards for humans. Furthermore, nonpoint source pollutants can affect the aesthetic enjoyment of environmental and recreational amenities.

Environmental impacts, in the context of this study, are externalities arising from agricultural production. Specifically, agricultural production causes pollution that directly affects the production and/or consumption process of other sectors and the welfare of consumers without intervening market transactions (Buchanan and Stubblebine, 1962; Baumol and Oates, 1979). A useful classification system for externalities was provided by Baumol and Oates in their distinction between depletable and nondepletable externalities. Depletable externalities have individual effects - a specific individual bearing an environmental effect will preclude another individual bearing the cost. In contrast a nondepletable externality is collectively borne by a number of individuals. The importance of this distinction is that depletable externalities are much easier to measure. In the first place, the individuals affected can more readily be identified. Furthermore, the costs of these externalities can often be measured because the affected individuals have incentives to undergo expenditures to ameliorate these damages.

The limited past research on environmental costs therefore are focused on depletable externalities. Sediment damages affect water resource functions of government for which numerous cost estimates have been synthesized. Damages considered have included (1) shortened economic life of reservoirs, (2) sediment damages associated with flooding, (3) costs of clearing and maintaining drainage ditches, and (4) costs of removing sediment from water for municipal and industrial uses (Guntermann, Lee, and Swanson, 1975).

Another component of depletable externalities that has had some empirical research concerns costs of pesticide damages. The primary means of measuring these damages has been to estimate medical costs and workman compensation payments to humans and veterinarian costs for domestic animals related to pesticides (Langham, Headley and Edwards, 1972). The medical costs reflected acute effects of pesticides rather than chronic health effects that were not sufficient to warrant health expenditures or were not directly relatable to pesticide damages.

Another depletable externality that has received some attention concerns damages to wildlife recreation. To analyze these damages, studies utilized the standard recreation demand methodology of inferring benefits from individual market expenditures on recreation. The adaptation for these studies is that pollution affects the quality of recreation such that recreational experiences have less value to participants (Stevens, 1966; Shulstad and Stoevener, 1978).

Although a comprehensive study of the costs of nonpoint pollution associated with new crop production would have to estimate such costs, methodological problems would exist in such estimation. All the pollutants from agriculture of concern in this study probably influence wildlife habitats for at least some species. Estimating the impact of agricultural pollutants separate from pollutants from other sources and other disturbances to wildlife and then relating this to behavior of recreators, however, would require a comprehensive multidisciplinary study.

The problems of estimating nondepletable environmental costs are even more difficult. The contribution of pollution to deterioration in aesthetics and damage of ecological systems typically affect a large number of people. The aspect of biomagnification of pesticides in particular would indicate possible damage over a long period of time. The collective nature of these costs makes inference of their magnitude from individual market behavior difficult. Some economists have approached this problem by eliciting preferences through the use of surveys (Cicchetti and Smith, 1976; McConnell, 1977). This approach has questionable validity, however, because of its separation from actual behavior. In part, the number of potential collective benefits from environmental costs would require a large number of separate estimates to ascertain whether all costs are being considered. For example, Krutilla and Fisher have argued that collective benefits from wildlife exist for several categories of people other than the actual participants--those who value preservation of aspects of the environment, those who value the option of participating in the future, and those who may benefit from scientific advances associated with preservation of wildlife.

A complete, thorough analysis of all environmental costs resulting from placing forest and pasture land in crop production is impossible because it is too difficult to estimate the multitude of impacts of a change in water quality (Meta Systems, Inc., 1979). Even if some of these costs are measured, political decisions would be necessary to weigh the benefits of new cropland with measurable and nonmeasurable environmental costs. Such problems have led some economists to recommend that all costs and benefits be measured in the most scientifically valid manner and presented to political decision-makers in such a form (McKean, 1968; Barkley and Seckler, 1972). From this viewpoint, the environmental impacts estimated in this study can be conceptualized as part of an economic decision framework. Although this approach is modest in its objectives, it does not use economic methodology to estimate costs that are likely to be misleading and/or incomplete given the state of the art.

The methodology developed in this report was applied to Georgia for the period 1973-1976. The following sections report on this empirical application.

SECTION 4

LAND RESOURCES AND USE PATTERNS IN GEORGIA

This section summarizes the land resources of Georgia. SRGs, which are the basic units of analysis used in this report, are identified and characterized. LRAs are characterized according to SRGs and land use patterns.

LAND RESOURCE AREAS

The Southeastern United States contains five LRAs as identified by the Soil Conservation Service (Austin, 1965), with the three largest extending into Georgia. The South Atlantic and Gulf Slope Cash Crop, Forest, and Livestock Region makes up almost 75 percent of the state. Over 90 percent of Georgia's cropland is found within this region. However, all regions of Georgia, which are subdivided into eight LRAs, will be considered in this study.

Georgia has a great number of parent materials as well as a wide range of climatic and topographic conditions that are largely responsible for the great number of different soils. The eight LRAs, better known as provinces, are: (1) Sand Mountain (LRA 129), (2) Southern Appalachian Ridges and Valleys (LRA 128), (3) Blue Ridge Mountain (LRA 130), (4) Southern Piedmont (LRA 136), (5) Carolina and Georgia Sand Hills (LRA 137), (6) Black Lands (LRA 135), (7) Southern Coastal Plain (LRA 133), and (8) Atlantic Coast Flatwoods (LRA 153). The general map of Georgia with physiographic provinces is shown in Figure 5. In this report, the two smallest LRAs have been combined with others and therefore the results will be reported for only six LRAs. Sand Mountain was included in Southern Appalachian Ridges and Valleys, and Black Lands was included in the Southern Coastal Plain.

Total land area occupied by each of the six LRAs within Georgia, as reported in the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970), is shown in Table 1. The state had 7.0 million hectares in Classes I-III, 1.9 million hectares of marginal land, 2.0 million hectares of wetlands, and 2.9 million hectares of submarginal land. Only half of Georgia's total land area has been classified as suitable for cultivation. Every land resource area has substantial acreages of marginal and submarginal land.

As indicated earlier, this study uses SRG classifications that are based on the dominant soil series in each soil association. The SRGs of Georgia are characterized in Appendix Table C1. Some SRGs have the same general

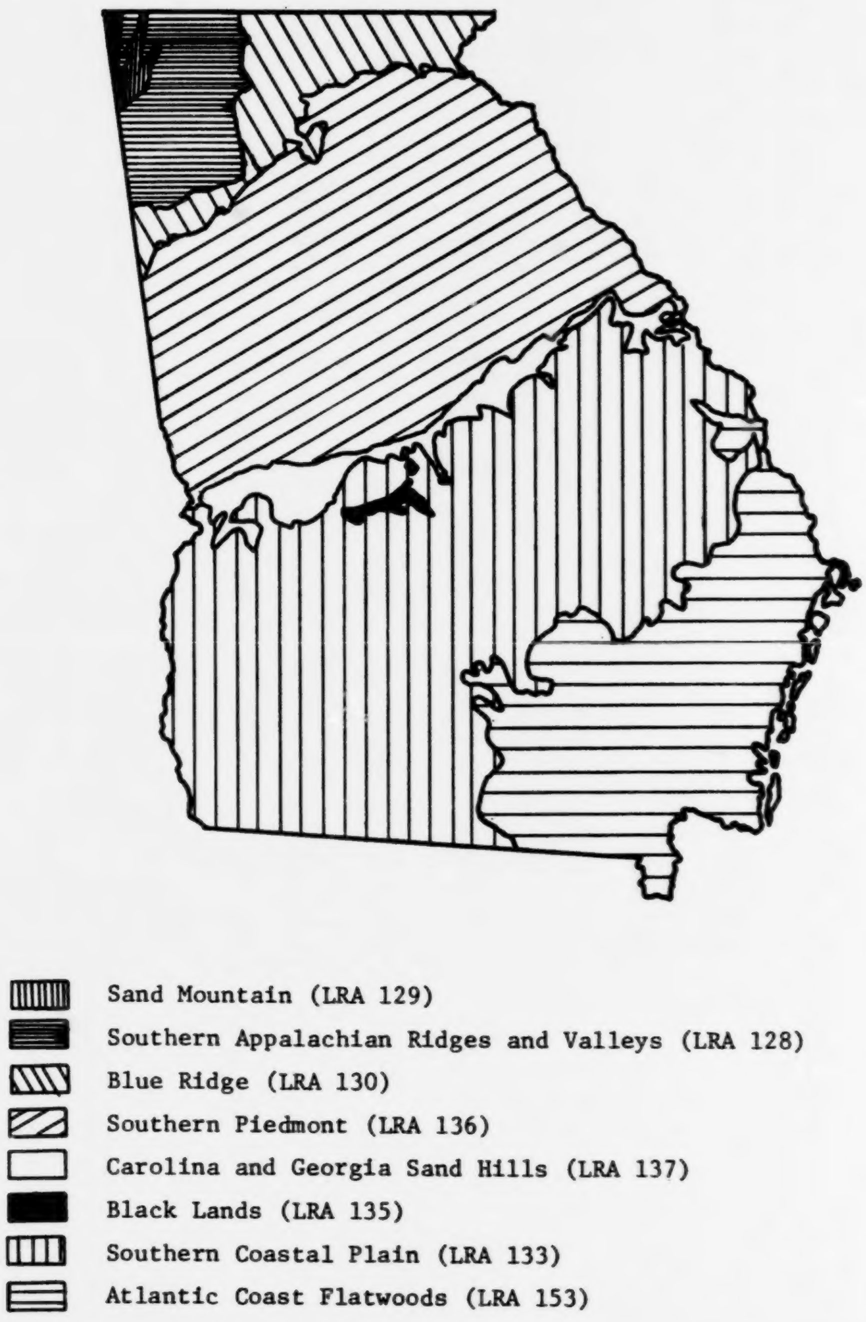

▥ Sand Mountain (LRA 129)
▤ Southern Appalachian Ridges and Valleys (LRA 128)
▧ Blue Ridge (LRA 130)
▨ Southern Piedmont (LRA 136)
□ Carolina and Georgia Sand Hills (LRA 137)
■ Black Lands (LRA 135)
▥ Southern Coastal Plain (LRA 133)
▤ Atlantic Coast Flatwoods (LRA 153)

Figure 5. Land resource areas of Georgia.

TABLE 1. TOTAL CULTIVATABLE, MARGINAL, WETLANDS AND SUBMARGINAL LANDS IN GEORGIA BY LAND RESOURCE AREA*

Land Resource Area	Inventoried Land Area*					Total Land Area**	Percentage of Land Area Inventoried
	Cultivatable (I,II,III)	Marginal (IV)	Wetlands (V)	Submarginal (VI,VII,VIII)	Total Inventory#		
			(Hectares)				(Percent)
Appalachian Valley and Ridges	264,090	106,829	0	313,491	684,410	752,791	91
Mountain	83,390	62,025	234	315,134	460,783	652,370	71
Piedmont	1,848,727	1,019,883	15,364	1,149,728	4,033,702	4,394,230	92
Sand Hills	318,838	130,618	46,703	149,135	645,294	766,488	84
Southern Coastal Plain	3,596,706	471,143	928,198	604,704	5,600,751	5,779,257	97
Atlantic Coast Flatwoods	897,139	103,305	1,004,182	376,633	2,381,259	2,707,043	88
Total	7,008,890	1,893,803	1,994,681	2,908,825	13,806,199	15,052,179	92
			(Percent)				
Distribution	50.8	13.7	14.4	21.1	92	100	

*Source: U.S. Department of Agriculture, Soil Conservation Service. Georgia Conservation Needs Inventory, 1967. Washington, D.C., April, 1970.

#Certain Federal land, urban build-up and water areas were excluded from the inventory.

**Source: U.S. Department of Commerce, Bureau of the Census. 1969 Census of Agriculture. Washington, D.C., 1972.

name, but are different because of their slopes. Capability class is based on dominant soil series and takes into consideration average slope. Other SRG characteristics reported in this table include hydrologic soil group, suitability, and erodibility factor. Appendix Table C2 gives the breakdown of land area by SRG, showing the number of hectares of each SRG within the six LRAs.

The SRGs have been grouped by capability class and their areas aggregated for each LRA in Table 2. This approach provides a second approximation of the distribution of land area by capability class for the various LRAs. The data in Tables 1 and 2 were compared to determine whether the two samples were drawn from similar populations. Using a variety of non-parametric tests for two related samples (Siegel, 1956), the null hypothesis that the data from the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970) differed significantly at the 10 percent level from the data developed in this study using SRGs was not rejected. While there are differences for some individual categories, the approach used in this study appears to be generally consistent with the approach reported in CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970). Furthermore, the use of the dominant soil series to characterize a soil association did not introduce an overall bias in the data set.

LAND USE PATTERNS

A thorough inventory of land cover and land-use patterns for Georgia is presented in the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970). A summary of the inventory by LRA is presented in Appendix Tables C3, C4, and C5. Over 13 million hectares were identified in row crops, forest, conservation use only, pasture and rangeland, orchards, close grown crops, and idle land. Almost 70 percent is in forest and almost 11 percent in row crops.

Crop land is predominantly on land classified as suitable for cultivation (Appendix Table C3). Only 6.3 percent of total row crop area was on marginal and submarginal land (includes wetlands). However, three LRAs - Mountains, Piedmont, and Sand Hills - had over 10 percent of their crops on marginal and submarginal land. The Southern Coastal Plain, the major agricultural area of the state, had one million hectares on cultivatable land. This LRA also had the largest area of marginal and submarginal land in crop production, 50 thousand hectares. The Piedmont with 21 thousand hectares has the second largest area of marginal and submarginal cropland, followed by the Atlantic Coast Flatwoods with 12 thousand hectares.

The 9.6 million hectares of forests are more evenly balanced among the classes (Appendix Table C4). Of Georgia's total forest acreage, 37.9 percent is on cultivatable land, 15.4 percent on marginal land, 20.1 percent on wetlands, and 26.6 percent on submarginal land. The Piedmont and Southern Coastal Plain each have over a million hectares of forests on land classified as suitable for cultivation. In fact, there are over 3.6 million hectares of forests on cultivatable land.

TABLE 2. CULTIVATABLE, MARGINAL, WETLANDS AND SUBMARGINAL LANDS IN GEORGIA BASED ON DOMINANT CAPABILITY CLASSES ASSIGNED TO SOIL RESOURCE GROUPS

Land Resource Area	Cultivatable (I,II,III)	Marginal (IV)	Wetlands (V)	Submarginal (VI,VII,VIII)	Total
			(Hectares)		
Appalachian Valley and Ridges	157,330	32,180	58,459	504,826	752,795
Mountain	61,696	0	20,249	570,425	652,370
Piedmont	2,256,335	1,286,755	528,667	322,473	4,394,230
Sand Hills	115,430	423,913	31,297	195,848	766,488
Southern Coastal Plain	4,350,337	801,896	94,237	532,787	5,779,257
Atlantic Coast Flatwoods	1,189,334	821,548	272,086	424,075	2,707,043
Total	8,130,462	3,366,292	1,004,995	2,550,434	15,052,183
			(Percent)		
Distribution	54.0	22.4	6.7	16.9	100.0

Land use patterns of pasture and rangeland, conservation use only, orchards, close grown crops, and idle land have all been grouped together under the heading of Other Uses. Almost 75 percent of this land is classified as suitable for cultivation (Appendix Table C5). Only 2 percent of this land is classified as wetlands, and the remaining 25 percent is evenly split between marginal and submarginal land. According to this classification scheme, almost 960 thousand hectares are classified as cultivatable land in the Southern Coastal Plain, and over 650 thousand hectares classified as cultivatable in the Piedmont. The Piedmont has almost 190 thousand hectares classified as marginal land.

It is expected that a large proportion of new cropland will be converted from this Other Uses category. First, a large proportion of this acreage is on land suitable for cultivation. Secondly, it is more difficult and expensive to convert forestland to crop production. Also, if root harvesting equipment is not readily available the land may have to lie idle for several years to allow the tree roots to decay before the land can be put in cultivation.

SOIL BANK LAND

Total amount of land placed in the Soil Bank or CRP reached a peak in Georgia in 1960 with 430,001 hectares (U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service, Final Report Conservation Reserve Program: Summary of Accomplishments 1956-1970, 1970). Soil Bank land remained over 430 thousand hectares through 1963, then declined to 320 thousand hectares in 1967, 215 thousand hectares in 1968, and 100 thousand hectares in 1969. Essentially all contracts had expired by 1970.

The distribution of Soil Bank land by LRA in the late 1950's is presented in Table 3. Over 30 percent of the Soil Bank land was located in the Southern Coastal Plain, and 28 percent in the Piedmont. Twenty-five percent of Georgia's designated Soil Bank land was in grasses and legumes and 75 percent was planted in trees. These proportions varied substantially by LRA. In the Appalachian Valley and Ridges and Mountains more Soil Bank land was planted to grasses and legumes than trees. Almost 40 percent of the Piedmont's designated Soil Bank land was in grasses and legumes. Only 20 percent of the Southern Coastal Plain's designated Soil Bank land was in grasses and legumes. It would be expected that areas with a higher proportion of grasses and legumes might have relatively more conversion of Soil Bank land to cropland, other things being equal.

The distribution of land restricted to conservation use only by LRA and soil class is reported in Table 4. Total land area in this category for each LRA is very similar to the Soil Bank hectares shown in Table 3. Over 85 percent of this land is classified as suitable for cultivation, and ten percent is classified as marginal (Table 4).

TABLE 3. CONSERVATION RESERVE LAND IN GEORGIA IN 1956-1959 BY LAND RESOURCE AREA*

Land Resource Area	Proposed Trees	Proposed Grasses and Legumes	Other	Total
		(Hectares)		
Appalachian Valley and Ridges	1,985	3,092	634	5,711
Mountain	416	465	111	992
Piedmont	50,709	31,162	6,665	88,536
Sand Hills	17,267	3,632	470	21,369
Southern Coastal Plain	148,773	38,381	5,688	192,842
Atlantic Coast Flatwoods	7,572	458	42	8,072
Total	226,722	77,190	13,610	317,522
		(Percent)		
Distribution	71.4	24.3	4.3	100

*Source: U.S. Department of Agriculture, Agricultural Stabilization and Conservation Service. Georgia ASCS Annual Reports. Athens, Georgia, Annual.

TABLE 4. CULTIVATABLE, MARGINAL, WETLANDS AND SUBMARGINAL LAND UNDER CONSERVATION USE ONLY IN 1967*

Land Resource Area	Cultivatable (I,II,III)	Marginal (IV)	Wetlands (V)	Submarginal (VI,VII,VIII)	Total
			(Hectares)		
Appalachian Valley and Ridges	17,469	4,712	0	2,627	24,808
Mountain	6,475	1,616	0	389	8,480
Piedmont	98,328	24,396	61	9,566	132,351
Sand Hills	17,534	3,048	63	466	21,111
Southern Coastal Plain	273,911	19,156	1,482	7,831	302,380
Atlantic Coast Flatwoods	30,728	1,487	188	0	32,403
Total	444,445	54,415	1,794	20,879	521,533
			(Percent)		
Distribution	85.2	10.4	0.4	4.0	100

*Source: U.S. Department of Agriculture, Soil Conservation Service. Georgia Conservation Needs Inventory, 1967. Washington, D.C., April, 1970.

SECTION 5

ESTIMATION OF CHANGES IN LAND USE AND INPUT USAGE IN GEORGIA

The magnitude and type of land use changes are identified in this section. The type of land use changes considered relate to capability class, former agricultural use, and the type of crop grown on the land once it is converted to crop production. Special consideration is given to conversion of Soil Bank land to crop production. Having identified which crops are produced on the new crop land, it will be possible to measure changes in input usage, with particular attention focused on fertilizers and pesticides, which are potentially hazardous to the environment.

CHANGES IN CROP ACREAGE

The five principal crops in Georgia are corn, soybeans, peanuts, cotton, and tobacco. The combined acreage of these five crops accounts for over 95 percent of total row crop acreage in the State (U.S. Department of Commerce, Bureau of the Census, Census of Agriculture, 1974). Hence, this discussion will concentrate on these principal crops. The Southern Coastal Plains accounts for over 75 percent of Georgia's crop acreage. Of the other five LRAs, only the Atlantic Coast Flatwoods accounted for as much as 10 percent of Georgia's total crop acreage. The Appalachian Valley and Ridges, Mountain, and Sand Hills combined have only about 5 percent of Georgia's crop acreage. Corn accounted for over half of the total crop acreage over the 1973-1976 period; soybeans accounted for 20 percent of total crop acreage. Changes in crop acreage, however, are of particular interest in this study.

Changes in crop acreages over the 1973-1976 period for each LRA and the major crops are reported in Table 5. Total acreage for the five crops increased by 273 thousand hectares. Corn and soybeans were responsible for this increase: corn increased 238 thousand hectares and soybeans increased 98 thousand hectares. Peanuts and tobacco, which are generally more profitable than other row crops, are restricted by government acreage programs. Cotton acreage declined 73 thousand hectares over the period. Hence it may be concluded that new cropland was brought into production for corn and soybeans.

SHIFTS IN LAND USE PATTERNS

The types of land use patterns that had been converted to cropland over the 1973-1976 period were identified from surveys by the Soil Conservation Service and the Georgia Cooperative Extension Service. Their estimates of the percentage distribution of land use patterns were linked with the estimated cropland changes from this study to determine the number of hectares of woodland, pasture land, and other land that was placed in crop production (Table 6). Most of the new cropland was converted from woodland. Approximately 56 percent of the land had previously been woodland. Only 38 percent of the land placed in crop production was previously in pasture (Table 6).

Changes in land use patterns on land previously under the Soil Bank program were identified through the use of two additional surveys - one conducted by the Georgia Forestry Commission and one conducted as a part of the present study. The Georgia Forestry Commission study was concerned with the 280 thousand hectares of pine plantations that were established on Soil Bank land in Georgia between 1956 and 1960 (Georgia Forestry Commission, 1976). The objective of that study was to determine the amount of this acreage that remained in trees. With the last plantings in 1960, the final payment under the 10-year contracts was made in 1970. The average age of these plantations was 18 years in 1976. A random sample of 47 cases was included in the study for Georgia. Field foresters examined each tract to determine such factors as existing growing stock volume, volume removed in the past, and hectares converted to other uses.

TABLE 5. CHANGES IN LAND AREA OF FIVE MAJOR ROW CROPS IN GEORGIA, 1973-1976*

Land Resource Area	Row Crop Corn	Soybeans	Peanuts	Cotton	Tobacco	Total
			(Hectares)			
Appalachian Valley and Ridges	1,859	9,251	0	-5,530	0	5,580
Mountain	109	1,150	0	-644	0	615
Piedmont	10,203	27,707	0	-17,961	-156	19,793
Sand Hills	2,095	3,620	221	-5,010	-123	803
Southern Coastal Plain	202,047	52,607	5,278	-42,864	2,852	219,920
Atlantic Coast Flatwoods	21,218	3,957	184	-519	1,863	26,703
Total	237,531	98,292	5,683	-72,528	4,436	273,414

*Source: U.S. Department of Agriculture, Statistical Reporting Service, Georgia Crop Reporting Service. Georgia Agricultural Facts, 1969-1977, Athens, Georgia, October 1978.

TABLE 6. ESTIMATED CONVERSION OF WOODLAND, PASTURE AND OTHER LAND TO CROPLAND, GEORGIA 1973-1976

Land Resource Area	All New Cropland Woodland	Pasture Land	Other Land
	(Hectares)		
Appalachian Valley and Ridges	872	3,879	257
Mountain	14	197	0
Piedmont	3,741	12,656	4,173
Sand Hills	2,473	2,531	680
Southern Coastal Plain	126,500	81,831	12,231
Atlantic Coast Flatwoods	29,607	10,519	1,040
Total	163,207	111,613	18,381

Results of the survey indicate that 83 percent of the Soil Bank land originally planted in pines remained in trees through 1976 (Table 7). The average growing stock was almost 64 cords per hectare (Georgia Forestry Commission, p. 5, 1976). Many of the plantations were approaching sawtimber size, and some already contained sawtimber. As these trees approached sawtimber size, this land produced some $14 worth of wood per hectare per year (Georgia Forestry Commission, 1976).

The remaining 17 percent of the land in pine plantations had been cleared by 1976 (Table 7). Only one percent of the land had been placed in crop production by 1976. Trees on that land had been harvested at an early age and the land was converted to crops prior to 1973. A large portion of the land - 14.5 percent - had recently been harvested by clear cutting and was idle in 1976. Trees on some of this land may have been harvested in order to put the land into crop production; however, this conversion process would not be complete until after 1976.

A second survey was conducted to determine the amount of Soil Bank land that was converted from pasture to crops. Approximately 25 percent of the Soil Bank land had originally been planted to grasses and legumes. It would be expected that more of this land would be converted to cropland than had

TABLE 7. STATUS OF PINE PLANTATIONS ESTABLISHED IN GEORGIA UNDER THE 1956-1960 SOIL BANK, CONSERVATION RESERVE PROGRAM*

	Land Area	Distribution
	(Hectares)	(Percent)
Trees planted 1956-1960	280,867	100.0
Trees remaining 1976	233,120	83.0
Trees harvested 1976	47,747	17.0
Recently harvested	40,726	14.5
Converted back to agriculture	3,089	1.1
Urban or other development	2,247	0.8
Status for clearing unknown	1,686	0.6

*Source: Georgia Forestry Commission. A Report on the Current Status of the Pine Plantations Established in the State of Georgia Under the 1956 to 1960 Soil Bank, Conservation Reserve Program. Macon, Georgia, August 1976.

been the case with the Soil Bank land planted to trees. First, the conversion process for pastureland is fairly simple and can be completed without a delay in production. Secondly, beef prices were considered to be depressed between 1974 and 1976.

The study was designed to survey landowners who had participated in the Soil Bank program. The list of former participants in the program was stratified by geographic region in the state and a sample was randomly drawn from each region. Seventy landowners were surveyed to determine the status of their Soil Bank land in 1976.

The results of the survey indicated that 87.5 percent of the land planted to trees under the Soil Bank program remained in trees in 1976. The remaining acreage that was originally planted to trees (12.5 percent) had been harvested but remained idle in 1976. These figures are very similar to the Georgia Forestry Commission estimates. The survey also indicated that approximately 70 percent of the land planted to grasses and legumes under the Soil Bank program had been converted to crop production by 1976. Corn was the dominant crop planted on former Soil Bank land.

LAND USE CHANGES BY CAPABILITY CLASS

New cropland, which is identified as an increase in cropland over the 1973-1976 period, is estimated in this section according to specific SRGs and thus to capability classes. Two alternative approaches were considered. First, LANDSAT remote sensing data were used. Secondly, it was assumed that no change would occur in the distribution of cropland among the suitable, marginal, and submarginal for cultivation classifications from the CNI of 1967 (U.S. Department of Agriculture, Soil Conservation Service, 1970). The following paragraphs discuss the results obtained with these approaches.

Arrangements were made to have the LANDSAT digital data analyzed using the specialized computer facilities at the Georgia Institute of Technology. (LANDSAT data were processed on the Earth Resources Data Analysis System and the Georgia Tech Cyber 74.) The Engineering Experiment Station at Georgia Tech contracted to machine process LANDSAT digital data for the determination of land cover changes. The analysis was to result in land cover maps with overlay capacity. The major responsibilities of researchers at the University of Georgia included acquisition of all LANDSAT tapes, ground truth acquisition, and determination of training field locations and geographic control points on the computer system. Initially, change detection was planned for the period 1972 to 1976, but because no good cloud-free imagery was available in 1972 (only one satellite was in orbit at that time), computer compatible tapes covering four LANDSAT scenes in Georgia were ordered for 1973 and 1976.

After the appropriate ground truth information had been acquired and entered into the computer, processing of the tapes was initiated. However, several problems as described below were encountered. Finally, it was determined that land use changes could not be identified accurately using these procedures.

The best LANDSAT tapes that could be identified during mid-summer had some cloud cover that affected quality of the imagery. There is generally less cloud cover in Georgia during winter. Also, with mid-summer scenes crops were at so many different stages of growth that it was almost impossible to classify row crops into one homogeneous group. Because both the 1973 and 1976 scenes were taken before this study was begun, we could not know what stage of growth the row crops were in. Furthermore, LANDSAT technology is not fully developed. NASA recommended that the LANDSAT scenes be geo-referenced before they were classified. This process failed and the scenes had to be classified before they were geo-referenced.

Although several difficulties were encountered in using LANDSAT imagery, the approach offers a great deal of potential for detecting land use change. Perhaps the experiences and failures of LANDSAT technology encountered in this study will be helpful in future efforts.

With the second approach, new cropland was distributed among suitable, marginal, and submarginal classifications according to the distribution of land already in cultivation. Because the observed land use changes for the 1973-1976 period were small relative to total land area in each county, there was sufficient land area in each of these classifications to meet these requirements. The following discussion of land use changes by capability classes is based on this approach.

New cropland estimates are reported in Table 8. For the 1973-1976 period, 293 thousand hectares of agricultural land were shifted to crop production. Over 12 percent of the new cropland was on land classified as marginal or submarginal. Another 12 percent of the new cropland was on land classified as suitable for cultivation and formerly under the Soil Bank program. Thus 25 percent of all new crop production (74.5 thousand hectares) was on marginal, submarginal, and/or Soil Bank land.

Data in Table 8 show the distribution of marginal, submarginal, and Soil Bank land by LRA. Eighty-five percent of the marginal and submarginal land brought into crop production was in the Southern Coastal Plain and Atlantic Coast Flatwoods. Most of the Soil Bank land classified as suitable for cultivation (85 percent), however, was in the Piedmont and Southern Coastal Plain. Much of the Atlantic Coast Flatwoods that was placed in crop production during this period was wetlands, which are classified as submarginal land in their natural state. With proper drainage, however, these soils can be quite productive.

Over half of the marginal, submarginal and Soil Bank land placed in crop production (41.1 thousand hectares) was in the Southern Coastal Plain. In the Piedmont and Atlantic Coast Flatwoods, 12 thousand and 14 thousand hectares, respectively, were placed in crop production on marginal, submarfinal, and Soil Bank land. The three remaining LRAs each had less than 4,000 hectares of marginal, submarginal, and Soil Bank land placed in crop production.

TABLE 8. ESTIMATED LAND AREA CONVERTED TO CROP PRODUCTION BY LAND RESOURCE AREA, GEORGIA 1973-1976

Land Resource Area	Total	Soil Bank	Non-Soil Bank
		(Hectares)	
Land Suitable for Cultivation			
Appalachian Valley and Ridges	4,490	3,265	1,225
Mountain	176	103	73
Piedmont	17,496	9,011	8,485
Sand Hills	3,593	1,126	2,467
Southern Coastal Plain	201,847	22,405	179,442
Atlantic Coast Flatwoods	28,039	1,057	26,982
Total Cultivatable	255,641	36,967	218,674
Marginal and Submarginal Land			
Appalachian Valley and Ridges	518	303	215
Mountain	35	0	35
Piedmont	3,073	993	2,080
Sand Hills	2,089	216	1,873
Southern Coastal Plain	18,715	1,826	16,889
Atlantic Coast Flatwoods	13,128	487	12,641
Total Marginal and Submarginal	37,558	3,825	33,733
Total State	293,199	40,792	252,407

CHANGES IN INPUT USAGE

Considering that cotton acreage declined and peanut and tobacco acreages were restricted by government programs, it was assumed that land was brought into crop production to produce corn and/or soybeans, which experienced tremendous increases in acreage between 1973 and 1976. Therefore, input usage was estimated for corn and soybeans.

The enterprise budgets for crops produced on new cropland developed in this study used updated estimates of previously published production costs (McArthur, 1971; U.S. Department of Agriculture, Economic Research Service, Commodity Budgets, 1975; U.S. Congress, 1977; Paxton, 1977; and Wise, 1974). These budgets were reviewed for accuracy by personnel in the Economics, Statistics, and Cooperatives Service, U.S. Department of Agriculture and Cooperative Extension Service. Representative budgets for corn and soybeans are shown in Tables 9 and 10. These budgets reflect state average yields; however, in subsequent analyses yields are estimated for each SRG. Production costs were also assumed to vary with yields. Land with below-average yields was assumed to have production costs that were slightly below the average. Each 10 percent reduction in yields below the state average was assumed to result in a 7 percent reduction in variable costs. This assumption may affect net farm income estimates on marginal and submarginal cropland, but it would have no effect on environmental loadings.

State specialists from the Cooperative Extension Service in Georgia helped estimate the amounts of herbicides, insecticides, and fungicides used on corn and soybeans. The procecure used to estimate application rates for these chemicals involved updating the Pesticide and General Farm Survey that was conducted in 1971 (USDA, Economic Research Service, 1971). Lists of chemicals identified in that survey along with amounts used per acre in 1971 were sent to state specialists to estimate the type and amount of chemicals used in 1976. This approach was used to determine representative usage rather than recommended usage. A comparison of the 1971 survey results with estimated usage in 1976 reveals that pesticide usage has generally increased since 1971. Also, a much greater variety of chemicals was being used in 1976. Names of pesticides and quantities used in Georgia will be presented in the next section.

TABLE 9. REPRESENTATIVE INPUT USE AND COSTS PER HECTARE OF CORN FOR GEORGIA, 1976

Item	Unit	Quantity	Price	Cost
Labor	hr.	11.98	2.62	31.41
Seed	kg.	12.57	1.34	16.90
Fertilizer, 5-10-15	kg.	671.62	0.11	70.72
Anhydrous ammonia	kg.	112.08	0.33	37.06
Lime	MT	0.74	17.05	12.65
Herbicide	kg.	2.80	5.98	16.80
Tractor	hr.	9.88	2.30	22.73
Machinery	-	-	-	8.90
Interest on operating capital (6 months)	dol.	217.17	0.09	19.55
Total preharvest costs	dol.	-	-	236.72
Combining	ha.	1.0	39.54	39.54
Hauling	kg.	3879.53*	0.001	3.06
Total harvest costs	dol.	-	-	42.60
Preharvest and harvest costs	dol.	-	-	279.32

*Average yield per hectare of corn for Georgia, 1976.

TABLE 10. REPRESENTATIVE INPUT USE AND COST PER HECTARE OF SOYBEANS FOR GEORGIA, 1976

Item	Unit	Quantity	Price	Cost
Labor	hr.	8.40	2.62	22.02
Seed	kg.	60.49	0.29	17.57
Inoculant	kg.	0.28	NA	NA
Fertilizer, 0-10-20	kg.	447.75	0.13	58.32
Lime	MT	0.74	17.05	12.65
Herbicide	kg.	1.23	13.53	16.66
Pesticide	kg.	3.36	0.77	2.59
Tractor	hr.	5.78	1.89	10.92
Machinery	-	-	-	21.89
Interest on operating capital (6 months)	dol.	162.62	0.09	14.64
Total preharvest costs	dol.	-	-	177.26
Combining	ha.	1.00	37.06	37.06
Hauling	kg.	1568.90*	0.003	4.62
Tractor and equipment	hr.	1.85	2.31	4.27
Total harvest costs	dol.	-	-	45.95
Preharvest and harvest costs	dol.	-	-	223.21

*Average yield per hectare of soybeans for Georgia, 1976.

SECTION 6

ESTIMATED ENVIRONMENTAL IMPACT OF LAND USE CHANGES IN GEORGIA

The environmental impacts of placing marginal, submarginal, and Soil Bank land in crop production are described in detail in this section. Such factors as sediment, fertilizer, and pesticide loadings are quantified so that they can be compared in a trade-off fashion with income and employment resulting from the increased production.

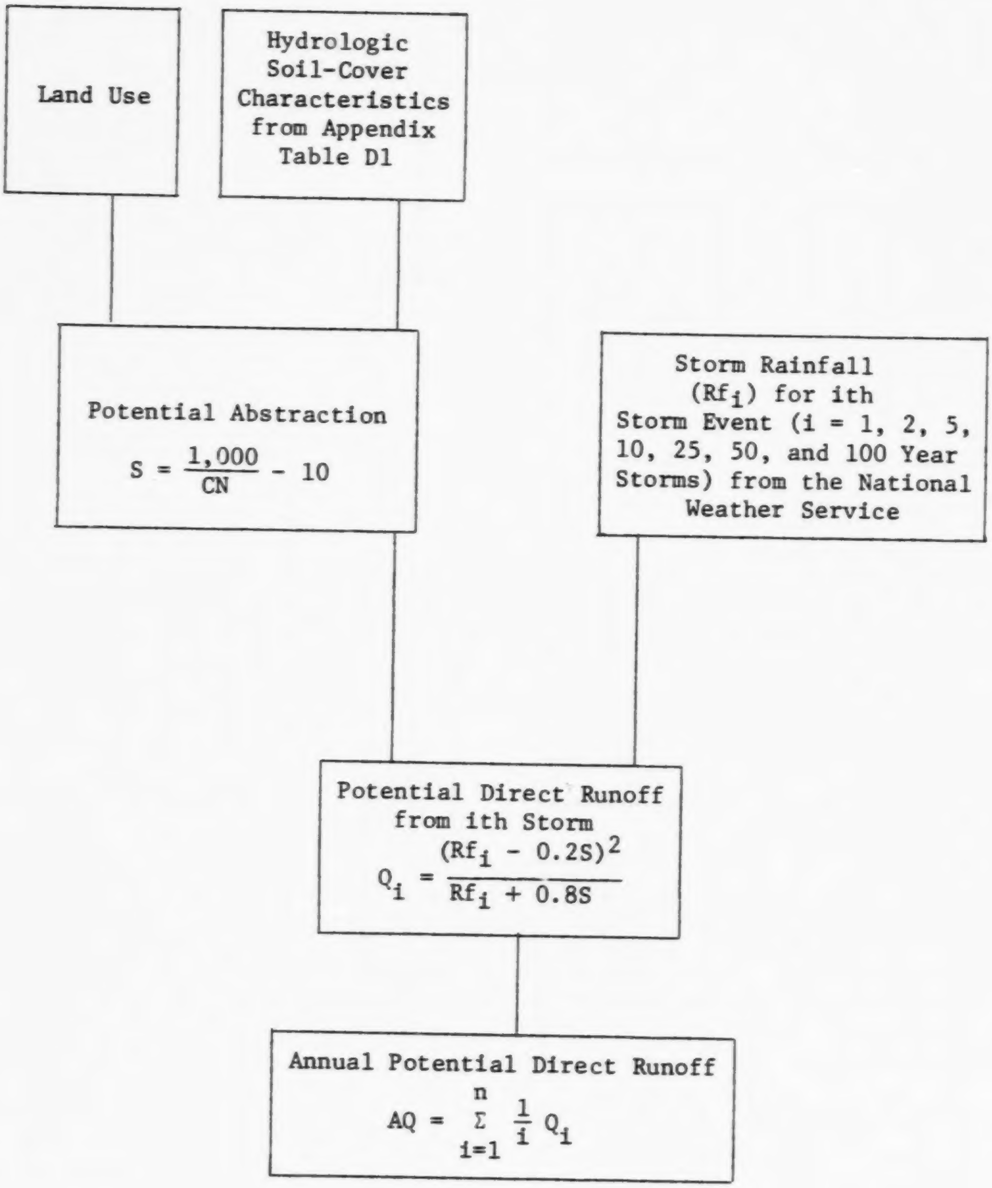
SEDIMENT AND RUNOFF DATA

The data used to calculate runoff and sediment yield are discussed in the following paragraphs. Estimates of soil and cover conditions are used with storm rainfall data to calculate potential runoff. Estimates of climatic, soil, topographic, and management practices are used to determine erosion rates. Erosion rates are then multiplied by sediment delivery ratios to determine sediment yield.

Data sources and procedures for calculating annual potential runoff are presented in Figure 6. Runoff curve numbers (Appendix Table D1), which are related to soil and cover conditions, are used to calculate potential abstraction (S) for the major agricultural uses - crops, forest, and pasture. Potential abstraction is then used to calculate potential direct runoff for 1, 2, 5, 10, 25, 50, and 100 year storms. Annual potential direct runoff is then calculated as the weighted average of direct runoff for each of these storm events, with the weights based on the probability of occurrence for each storm.

Sediment loading calculations and data sources are presented in Figure 7. Storm soil losses from a cultivated field are directly proportional to an interaction term, energy-intensity (EI), which is the product of rainfall energy and the maximum 30-minute intensity. The EI values are summed to obtain an annual rainfall-erosivity index for a given location. Georgia's annual index, which serves as the R factor, is shown in Appendix Table D2.

The most significant soil characteristics affecting soil erodibility are texture, organic matter content, soil structure, and permeability. The K values, which have been assigned to different soils by the Soil Conservation Service, are shown in Appendix Table C1 for the 74 SRGs identified in this report.



Land Use
Hydrologic Soil-Cover Characteristics from Appendix Table D1
Potential Abstraction
$S = \frac{1,000}{CN} - 10$
Storm Rainfall (Rf_i) for ith Storm Event (i = 1, 2, 5, 10, 25, 50, and 100 Year Storms) from the National Weather Service
Potential Direct Runoff from ith Storm
$Q_i = \frac{(Rf_i - 0.2S)^2}{Rf_i + 0.8S}$
Annual Potential Direct Runoff
$AQ = \sum_{i=1}^{n} \frac{1}{i} Q_i$

Figure 6. Schematic showing calculation of annual potential direct runoff.

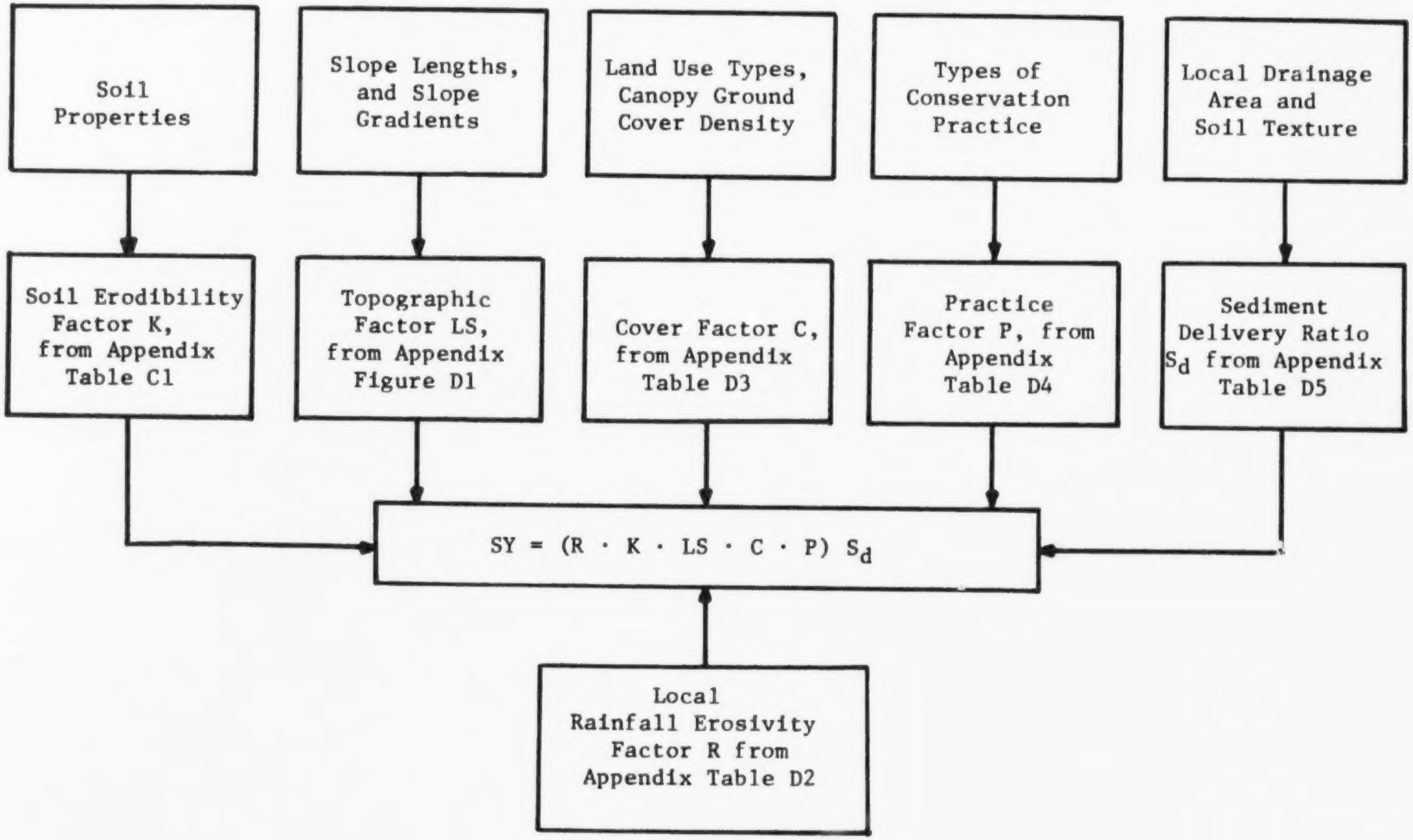

Soil Properties
Slope Lengths, and Slope Gradients
Land Use Types, Canopy Ground Cover Density
Types of Conservation Practice
Local Drainage Area and Soil Texture
Soil Erodibility Factor K, from Appendix Table C1
Topographic Factor LS, from Appendix Figure D1
Cover Factor C, from Appendix Table D3
Practice Factor P, from Appendix Table D4
Sediment Delivery Ratio S$_d$ from Appendix Table D5
SY = (R · K · LS · C · P) S$_d$
Local Rainfall Erosivity Factor R from Appendix Table D2

Figure 7. Schematic showing calculation of sediment loading from surface erosion.

Slope length (L) and slope gradient (S) are combined into a single topographic factor, LS. The LS factor for gradients up to 60 percent and slope lengths to 600 meters is obtained from the Slope-Effect Chart, Appendix Figure D1.

The plant cover or cropping management factor (C) relates to the effect of cover on soil loss. The basic soil loss is the rate at which the field would erode if it were continuously in tilled fallow. The equation's factor C indicates the percentage of this potential soil loss that would occur if the surface was partially protected by some particular combination of cover and management. The C values used in this study are reported in Appendix Table D3.

The erosion-control practice factor (P) accounts for control practices that reduce the erosion potential of runoff. Contouring influences drainage patterns, runoff concentration, and runoff velocity, whereas terracing only reduces the length of the slope. Control practice values for contouring and terracing are shown in Appendix Table D4.

Estimates of sediment yield are based on sheet and rill erosion as calculated by the USLE and the sediment delivery ratio as determined by texture of the soil and size of drainage area. Sediment yields were calculated for new cropland on each SRG, LRA, and the entire state.

The smallest drainage areas that produce a perennial stream within the various LRAs, as shown in Appendix Table D5, were used to compute sediment delivery ratios. Delivery ratios for the various LRAs are also shown in Appendix Table D5. All SRGs falling within Sand Mountain (LRA 129), Southern Appalachian Ridges and Valleys (LRA 128), Blue Ridge Mountain (LRA 130), and Southern Piedmont (LRA 136) above the fall-line, were considered to have a medium textured topsoil. Those below the fall-line with Carolina and Georgia Sand Hills (LRA 137), Black Lands (LRA 135), Southern Coastal Plain (LRA 133), and Atlantic Coast Flatwoods (LRA 153) were considered to have a sandy textured topsoil.

Fertilizer losses are assumed to be related to empirical estimates of runoff and sediment yield. Because no state estimates were available to determine what percentage of applied fertilizers was lost by runoff and erosion, national estimates were used. It was believed that this approach would provide conservative estimates of the quantity of fertilizer losses. In the present study, it is assumed that, on the average, 6 percent of applied nitrogen is lost by erosion, 2 percent is lost by runoff, and 2 percent moves through the soil to groundwater. No attempt was made to keep track of groundwater pollution, however, as the principal focus of this study was to account for pollution in surface water. Land with an erosion rate that differs from the state average was assumed to lose proportionately more or less nitrogen than the 6 percent state average linked to erosion. Also, it is assumed that nitrogen loss on land with a runoff rate that differed from the state average would differ proportionately from the 2 percent linked to runoff.

It is assumed that approximately 15 percent of the phosphorus applied as chemical fertilizer on cropland would be lost on the average. Since phosphate sorbs strongly on soil and resists leaching, phosphorus loss is closely related to erosion. It is assumed that cropland with an erosion rate equal to the state average would lose 15 percent of the applied phosphorus, whereas cropland with higher erosion rates would lose proportionately more phosphorus. Likewise, land with an erosion rate below the state average would lose proportionately less than 15 percent of its phosphorus applied as chemical fertilizer.

The following subsections report empirical estimates of environmental loadings from placing marginal, submarginal, and Soil Bank land in crop production during the 1973-1976 period. Similar estimates for all new cropland are reported in Appendix Tables E1 through E5.

RUNOFF AND SEDIMENT YIELD

Water quality can deteriorate as the result of agricultural pollutants being transported from fields to water bodies. The two principal transport processes, as mentioned earlier, are direct runoff and sediment movement. First, water quality is affected by the mere presence of soil in suspension. In addition, as sediment is deposited in streams or lakes, the use and appearance of these water resources may be adversely affected. Secondly, water and sediment may carry pesticides and plant nutrients, which also deteriorate water quality.

Changing land use from trees or grasses to crops increases runoff and erosion. There is only a small increase in runoff, as evidenced in Table 11. Placing marginal, submarginal, and Soil Bank land in crop production increases runoff 1.93 centimeters per hectare on the average. Rather than concentrating on the change in runoff, it is probably more important to look at the actual level of runoff from cropland because runoff affects sediment, fertilizer and pesticide loadings. Table 11 presents estimated runoff from the new cropland. Average runoff for new cropland on marginal, submarginal and Soil Bank land is 9.35 centimeters per hectare annually. Runoff is highest in the Atlantic Coast Flatwoods.

Placing land in crop production generally results in higher annual erosion and hence higher sedimentation than would occur if the land had remained in forest or pasture. Increased sediment yields as a result of the shift in land use (Tables 12 and 13) indicate that sediment from agriculture may become a significant problem in the future unless better land use planning and good management are utilized. Sediment yield from new cropland has increased over 20 metric tons per hectare in three LRAs - Appalachian Valley and Ridges, Mountain and Piedmont. Of the three, the Piedmont had the largest amount of new cropland, resulting in increased sediment yield of over 300,000 metric tons annually. The largest quantity of sediment from the new cropland, however, occurred in the Southern Coastal Plain, which has over 400,000 metric tons annually. It can be noted that this results from the large amount of new cropland, as the average per hectare was only 10.04 metric

TABLE 11. ESTIMATED RUNOFF FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Runoff	Increased Runoff	Runoff	Increased Runoff	Runoff	Increased Runoff
	(cm)	(cm)	(cm)	(cm)	(cm)	(cm)
Appalachian Valley and Ridges	9.04	0.64	6.73	1.14	7.04	1.09
Mountain	9.60	0.89	9.91	1.50	9.85	1.35
Piedmont	7.62	1.30	9.43	0.36	8.97	0.58
Sand Hills	5.44	2.62	10.74	1.02	7.29	2.06
Southern Coastal Plain	8.61	2.51	9.04	1.42	8.86	1.93
Atlantic Coast Flatwoods	12.24	3.35	11.38	2.41	12.17	3.28
State Total	9.63	2.69	9.07	1.17	9.35	1.93

*Includes marginal and submarginal Soil Bank land.

TABLE 12. ESTIMATED INCREASED SEDIMENT YIELD FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL, AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare	Total	Average per Hectare
	(1,000 MT)	(MT)	(1,000 MT)	(MT)	(1,000 MT)	(MT)
Appalachian Valley and Ridges	16.16	31.20	68.88	21.10	85.04	22.49
Mountain	2.11	60.44	2.35	22.80	4.46	32.41
Piedmont	96.96	31.56	25.34	25.02	322.30	26.68
Sand Hills	16.93	8.11	8.54	7.59	25.48	7.93
Southern Coastal Plain	193.52	10.35	218.84	9.77	412.36	10.04
Atlantic Coast Flatwoods	8.68	0.67	1.74	1.64	10.42	0.74
State Total	334.36	8.92	525.69	14.22	860.06	11.54

*Includes marginal and submarginal Soil Bank land.

TABLE 13. ESTIMATED SEDIMENT YIELD FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL, AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare	Total	Average per Hectare
	(1,000 MT)	(MT)	(1,000 MT)	(MT)	(1,000 MT)	(MT)
Appalachian Valley and Ridges	16.71	32.26	70.84	21.71	87.54	23.14
Mountain	2.17	62.07	2.41	23.45	4.58	33.26
Piedmont	99.91	32.52	231.78	25.74	331.69	7.46
Sand Hills	17.59	8.42	8.79	7.82	26.38	8.20
Southern Coastal Plain	203.29	10.86	225.06	10.06	428.35	10.42
Atlantic Coast Flatwoods	9.21	0.69	1.78	1.68	10.98	0.78
State Total	348.88	9.30	540.66	14.67	889.52	11.94

*Includes marginal and submarginal Soil Bank land.

tons. Sediment yields per hectare as reported in Table 13 are used in calculating nitrogen and phosphorus loss.

FERTILIZER LOSS

Estimates of annual nitrogen losses from crop production in 1976 on new cropland on marginal, submarginal, and Soil Bank land vary considerably by LRA (Table 14). Even ignoring the Mountain LRA, which had only minimal land area of the new cropland, nitrogen losses ranged from 3.98 kilograms per hectare in the Atlantic Coast Flatwoods to 11.00 kilograms per hectare in the Piedmont. The pollution potential from nitrogen fertilizer is greatest in the Southern Coastal Plain where large areas receive high rates of fertilizer. This LRA alone accounts for 61 percent of nitrogen losses from the new cropland.

Similarly, aggregate phosphorus losses from marginal, submarginal, and Soil Bank land, as reported in Table 15, are highest in aggregate in the Southern Coastal Plain (403 thousand kilograms annually) and the Piedmont (273 thousand kilograms annually). Phosphorus losses on a per-hectare basis, as shown in Table 15, are closely linked to sediment yield reported in Table 13. The new cropland in the Atlantic Coast Flatwoods lost very little phosphorus, whereas the other five LRAs had average phosphorus losses over 6 kilograms per hectare. This quantity of phosphorus loss is higher than the previously published estimates that were reviewed in an earlier section of this report. Most of those studies concerned all farmland, including forest and pasture land. Consequently, average erosion would be much less than the erosion rates from cropland on marginal, submarginal, and Soil Bank land in Georgia. Also, phosphorus application rates in Georgia are relatively high compared to the national average.

PESTICIDE LOSS

As indicated earlier, most of the increased row cropland in Georgia during the 1973-1976 period can be attributed to corn and soybeans. Several dozen destructive pests of corn and soybeans cause heavy losses virtually every year in Georgia. The names of these major pests can be seen in Table 16. This information was compiled from Georgia Agricultural and Entomology Extension Service Bulletins.

The pesticides identified by state specialists in the Georgia Cooperative Extension Service as being applied to corn and soybeans have been characterized by application rate, toxicity to fish and persistence in soil in Table 17. These pesticides are given a rating for each of the three factors. Pesticides are assigned the lowest rating for low application rate, relatively nontoxic and nonpersistent characteristics. Detailed guidelines for rating the various factors appear as footnotes in Table 17.

An index of potential environmental impact is calculated as the product of the ratings for quantity used, toxicity, and persistence. The value of

TABLE 14. ESTIMATED NITROGEN LOSS FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL, AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare	Total	Average per Hectare
	(1,000 Kg)	(Kg)	(1,000 Kg)	(Kg)	(1,000 Kg)	(Kg)
Appalachian Valley and Ridges	4.62	8.94	23.14	7.10	27.76	7.35
Mountain	1.82	52.01	2.29	22.24	4.10	29.85
Piedmont	44.81	14.60	87.97	9.78	132.78	11.00
Sand Hills	8.94	4.28	5.93	5.28	14.87	4.64
Southern Coastal Plain	156.18	8.36	213.50	9.54	369.68	9.00
Atlantic Coast Flatwoods	52.14	3.98	4.16	3.94	56.30	3.98
State Total	268.51	7.16	336.99	9.13	605.49	8.13

*Includes marginal and submarginal Soil Bank land.

TABLE 15. ESTIMATED PHOSPHORUS LOSS FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL, AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare	Total	Average per Hectare
	(1,000 Kg)	(Kg)	(1,000 Kg)	(Kg)	(1,000 Kg)	(Kg)
Appalachian Valley and Ridges	13.05	25.21	56.48	17.32	69.52	18.40
Mountain	2.15	61.49	2.42	23.51	4.57	33.21
Piedmont	84.13	27.42	188.57	20.94	272.64	22.59
Sand Hills	14.79	7.09	7.53	6.70	22.32	6.96
Southern Coastal Plain	186.96	10.00	216.19	9.67	403.16	9.82
Atlantic Coast Flatwoods	8.66	0.66	1.72	1.62	10.37	0.73
State Total	309.74	8.25	472.85	12.81	782.58	10.52

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*Includes marginal and submarginal Soil Bank land.

TABLE 16. ECONOMIC PESTS OF MAJOR CONCERN FOR CORN AND SOYBEANS IN GEORGIA

Crop	Weeds	Insects	Diseases
Corn	Annual grasses or grass-like weeds such as crabgrass, goosegrass, Texas panicum, and sandspur. Perennial grasses such as nutsedge and johnsongrass, both small-seeded and large-seeded broadleaf weeds such as lambsquarters, pigweeds, cocklebur, ragweed, sicklepod, jimpsonweed, tropic croton, Florida beggarweed and morning glories.	Fall Armyworm Corn Earworm Cutworm Common Stalk Borer Corn Leaf Aphid	Seed decay Seedling blight Seedling root rot
Soybeans	Same as above	Mexican Bean Beetle Velvet Bean Caterpillar Green Cloverworm Corn Earworms, Loopers Stink Bugs Lesser Cornstalk Borer	Seed decay Leaf spots Wildfire Downy mildew Bacterial blight Root-knot

TABLE 17. SELECTED CHARACTERISTICS RELATED TO POTENTIAL ENVIRONMENTAL IMPACT OF PESTICIDES USED ON CORN AND SOYBEANS IN GEORGIA, 1976

	Average Application Rate		Toxicity to Fish LC_{50} #		Approximate Persistence in Soil		
Pesticide	AI(mg)/ Hectare	Rating*	Mg/1	Rating**	Days	Rating##	Index of Potential Impact
Acephate	0.06	1					
Alanap	0.27	2	>180	1	20-60	1	2
Ametryne	0.03	1	≈50	1	30-90	1	1
Atrazine	0.63	3	12.6	2	300-500	3	18
Azodrin (Monocrotophos)	0.00	0	7.0	2	20	0	0
Benomyl	0.04	1	0.5	2	15	0	0
Bentazon	0.04	1	190	1	200-400	2	2
B. Thuringeinsis	0.04	1					
Captan†	0.10	1	0.13	3	20	0	0
Carbaryl	0.72	3	1.0	2	10	0	0
Chloroxuron	0.06	1	20	2	300-400	3	6
Copper Hydroxide	0.12	2	≈15	2	<100	1	4
Cyanazine	0.13	2	4.9	2	200-400	2	8
Dalapon	<0.01	0	>100	1	15-30	0	0
Dicamba	0.03	1	35	1	60	1	1
Di-Syston	0.01	0	.040	3	30	1	0
2, 4-D	0.17	2	4.5->50	2	30	1	4
2, 4-DB	0.01	0	4.0	2	30	1	0
DBCP	0.54	3					
DDT	0.00	0	.002	3	>1500	4	0
DMBP (Dinoseb)	0.15	2	.40	3	15-30	0	0
Endrin	0.00	0	.0002	3	>1000	4	0

(continued)

TABLE 17. (CONTINUED)

Pesticide	Average Application Rate		Toxicity to Fish LC_{50}#		Approximate Persistence in Soil		Index of Potential Impact
	AI(mg)/ Hectare	Rating*	Mg/1	Rating**	Days	Rating##	
E-Parathion	0.01	0	.047	3	7-11	0	0
EPTC	0.09	1	19.0	2	30	1	2
Lasso (Alachlor)††	0.13	2	2.3	2	40-70	1	4
	0.13						
Linuron††	0.01	1	16	2	120	2	4
	0.01						
Methomyl	0.37	2	≈.9	2	30	1	4
M-Parathion	0.54	3	1.9	2	7-11	0	0
Metribuzin	0.02	1	>100	1	150-200	2	2
Oryzalin	0.01	0	≈50	1	90-180	2	0
Paraquat	<0.01	0	400	0	>500	3	0
Phorate	0.00	0	.0050	3	15	0	0
Simazine	<0.01	0	5.0	2	200-400	2	0
Sulfur	0.06	1	200	0	≈60	1	0
Sutan (Butylate)	1.39	3	4.2	2	40-80	1	6
Thiram†	0.10	1	0.75	2	15	0	0
Toxaphene	1.08	3	.003	3	>1500	4	36
Trichlorofon	0.00	0	.16	3	30	1	0
Trifluralin	0.34	2	≈.1	3	120-180	2	12
Vernam (Vernolate)	0.01	0	9.6	2	50	1	0

(continued)

TABLE 17. (CONTINUED)

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*Rating was as follows: 0 = .01 or less except for linuron because used on both corn and soybeans, 1 = .02 to .10, 2 = .11 to .50, and 3 = >.50.

#Test commonly conducted for 24 to 96 hours on bluegills, trout or other fish.

**Rating was as follows: 0 = >200 (relatively nontoxic), 1 = 20-200 (slightly toxic), 2 = .5-20 (moderately toxic), and 3 = <.50 (highly toxic).

##Rating was as follows: 0 = <30 days (nonpersistent), 1 = 30-90 (slight persistence), 2 = 90-300 (low persistence), 3 = 300-540 (moderate persistence), and 4 = >540 (persistent).

†Used as seed treatment only.

††Used on both corn and soybeans.

the index, which is reported in Table 17, is zero for 20 out of 37 pesticides. Pesticides with an index value of zero were considered to have essentially no potential environmental impact and were therefore excluded from further analysis.

Pesticides with a nonzero index for potential environmental impact were considered in greater detail. Toxaphene had the maximum rating for all three factors, giving it the highest index value. Atrazine had the second highest index because of the relatively large quantity used and slightly toxic and moderately persistent characteristics. Other characteristics must also be considered in assessing potential environmental impact. These factors include mode of application, mode of transport, and most importantly, the biomagnification potential. The 17 pesticides having a nonzero index value are characterized according to these factors in Table 18. The only pesticide used in Georgia in 1976 on corn and soybeans that had a possibility of bioaccumulation was toxaphene, a chlorinated hydrocarbon. The biomagnification factor for toxaphene was 1, when referenced to DDT, which had a biomagnification factor of 2.

Application rates for pesticides with a potential for environmental impact were aggregated according to quantity of active ingredients. Using this approach, corn and soybeans had approximately the same application rates per hectare. Taking hectares of corn and soybeans on new cropland into consideration, aggregate amounts of pesticides with a potential environmental impact used on marginal, submarginal, and Soil Bank land are reported by LRA in Table 19. The Southern Coastal Plain had 110 metric tons of active ingredients of pesticides with a potential for environmental impact. The Piedmont and Atlantic Coast Flatwoods each had over 30 metric tons of active ingredients of these pesticides.

It would be difficult to assess the impact of any other pesticide except in isolated instances related to probability of rainfall shortly after application. The average monthly precipitation in Georgia is about 10.7 centimeters (Figure 8) with a minimum of about 6.9 centimeters in October and a maximum of about 14.2 centimeters in March and again in July. Rainfall patterns vary somewhat throughout the climatic regions but the peaks occur at the same time. Although monthly precpitation shows two distinct peaks, water resources data on river flow (Figure 9) give only one peak period of discharge. Rivers located in North, Central and South Georgia all show the same trend, with peak discharge rates in February, March, and April. Much higher evapotranspiration rates and groundwater recharge during the summer months offer some explanation of why precipitation in July has less influence on river flow than that in the early spring months.

Less vegetative cover, especially where row crops were harvested the previous year, would also have an important influence on runoff pattern and river flow during early spring months also. Because normal planting dates for corn and soybeans (Figure 8) correspond to minimum periods of runoff and discharge from rivers, rapidly degradable pesticides applied at or near planting would have little chance of polluting major rivers. Persistent pesticides applied to the soil surface at any time, however, could possibly

TABLE 18. APPLICATION INFORMATION, TRANSPORT MODE, AND BIOMAGNIFICATION OF SELECTED PESTICIDES CAPABLE OF ENVIRONMENTAL IMPACT IN GEORGIA, 1976

Pesticide	Crop Treated[*]	Chemical Group[#]	Comments on Mode and Time of Application[**]	Predominant Transport Mode[##]	Biomagnification Factor[†]
Alanap	S	H	Soil surface at planting	W	0
Ametryne	C	H	Directed spray 3-4 weeks after planting	SW	-
Atrazine	C	H	Soil surface at planting (may be incorporated)	SW	0
Bentazon	S	H	Broadcast spray 4-5 weeks after planting	W	-
Chloroxuron	S	H	Directed spray 2-3 weeks after planting	S	-
Copper Hydroxide	S	F	Incorporated at planting	W	0
Cyanazine	C	H	Soil surface at planting	SW	0
Dicamba	C	H	Directed spray 5-6 weeks after planting	W	0
2, 4-D	C	H	Broadcast or directed spray 4-6 weeks after planting	SW	0
EPTC	C	H	Incorporated 1 week prior to planting	SW	0
Lasso (Alachlor)	CS	H	Soil surface at planting	SW	0
Linuron	CS	H	Directed spray 3-4 weeks after planting	S	0
Methomyl	S	I	Broadcast spray 4 weeks after planting until bloom	U	0
Metribuzin	S	H	Soil surface at planting	W	-
Sutan (Butylate)	C	H	Incorporated 1 week prior to planting	S	0
Toxaphene	S	I	Broadcast spray 4 weeks after planting until bloom	S	1
Trifluralin	S	H	Incorporated 1 week prior to planting	S	0

(continued)

TABLE 18. (CONTINUED)

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*_C_ denotes chemicals used on corn, _S_ denotes chemicals used on soybeans, and _CS_ denotes chemicals used on both corn and soybeans.

#_F_ denotes fungicides, _H_ denotes herbicides, and _I_ denotes insecticides.

**Based on recommendations from Georgia Agricultural and Entomology Extension Service Bulletins.

##Where movement of pesticides in runoff from treated fields occurs, _S_ denotes those chemicals that will most likely move primarily with sediment, _W_ denotes those that will most likely move primarily with the water, and _SW_ denotes those that will likely move in appreciable proportion with both sediment and water.

†Rosmarie von Rumker, _et al_. _Production, Distribution, Use and Environmental Impact Potential of Selected Pesticides_, EPA 540/1-74-001. Environmental Protection Agency, Washington, D.C., 1974.

TABLE 19. AMOUNT OF PESTICIDES WITH POTENTIAL ENVIRONMENTAL IMPACT APPLIED TO NEW CROPLAND ON MARGINAL, SUBMARGINAL AND SOIL BANK LAND BY LAND RESOURCE AREA IN GEORGIA, 1976

Land Resource Area	Active Ingredients		
	Marginal and Submarginal Land	Cultivatable Soil Bank Land	Marginal, Submarginal, and Soil Bank Land
		(Metric Tons)	
Appalachian Valley and Ridges	1.39	8.77	10.16
Mountain	0.09	0.28	0.37
Piedmont	8.26	24.21	32.47
Sand Hills	5.61	3.03	8.64
Southern Coastal Plain	50.28	60.20	110.48
Atlantic Coast Flatwoods	35.27	2.84	38.11
State Total	100.90	99.33	200.23

reach major rivers in Georgia during spring and summer months. Pesticides applied to soybeans during the growing season would be most susceptible to storm runoff during July. Pesticides applied to either corn or soybeans with carry-over potential to spring of the following year would be susceptible to runoff and transport within major rivers of Georgia.

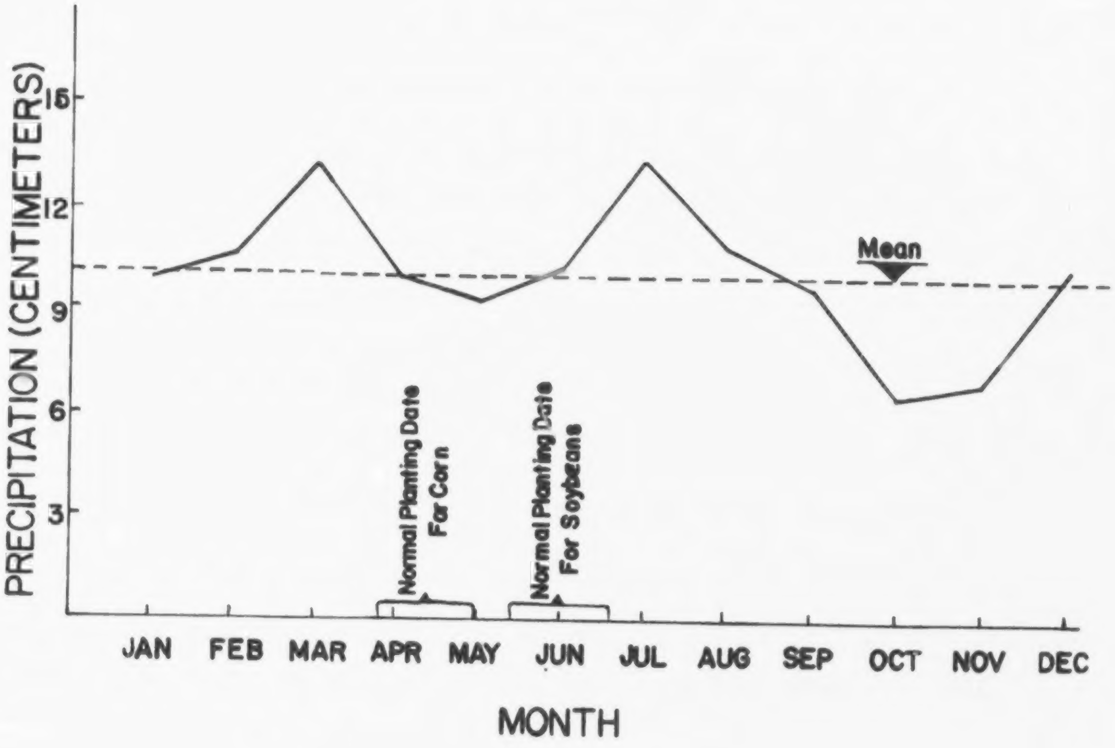

Figure 8. Average monthly precipitation for Georgia.

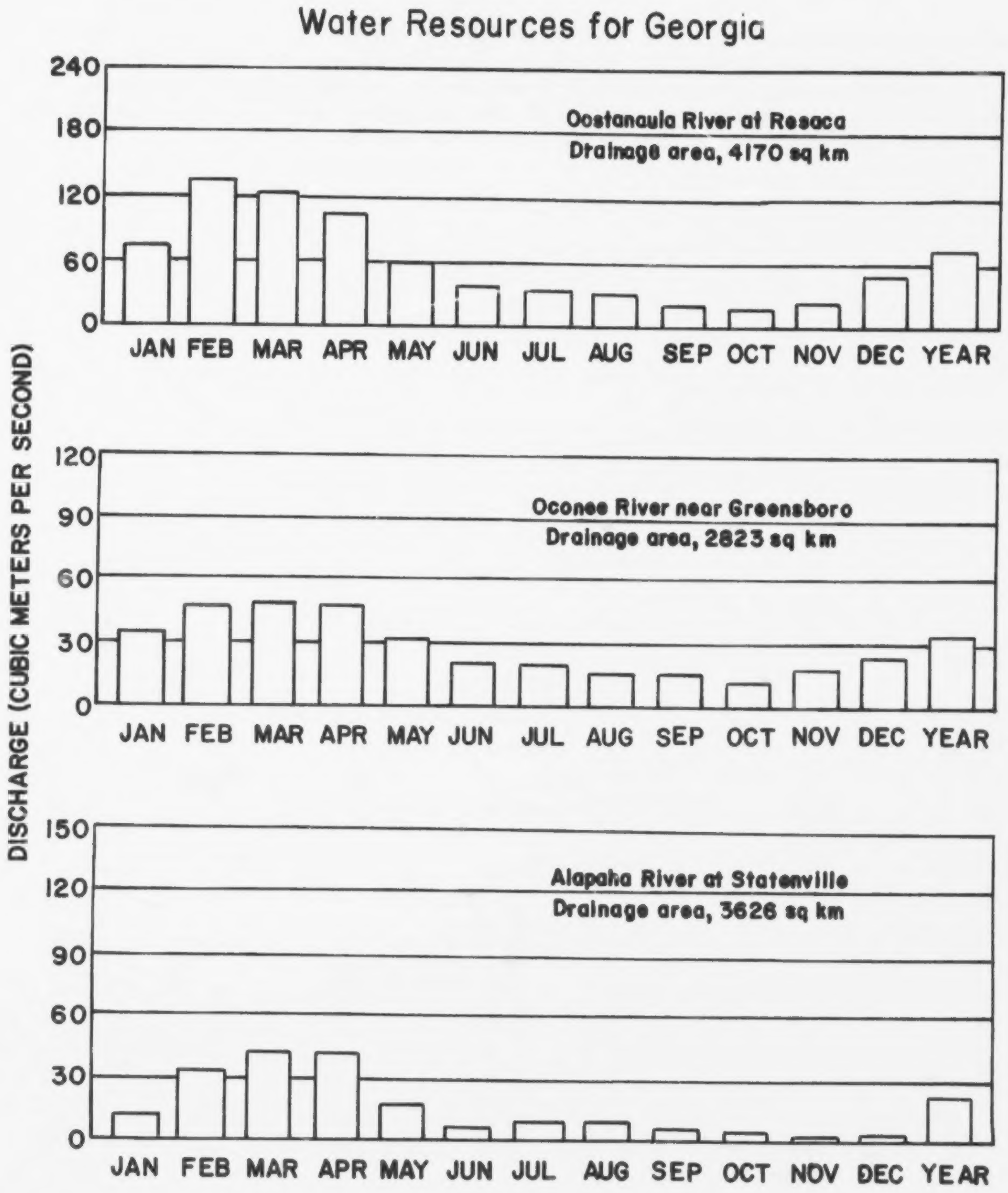

Figure 9. Median discharge for three representative gauging stations in Georgia.

SECTION 7

ESTIMATED ECONOMIC IMPACT ON GEORGIA

The 74.5 thousand hectares of new cropland on marginal, submarginal, and Soil Bank land produced $23.6 million worth of agricultural products in 1976 (Table 20). Half of this production was in the Southern Coastal Plain, 19 percent in the Atlantic Coast Flatwoods, and 12 percent was in the Piedmont. The following sections analyze the impact of this production on net farm income and Georgia's economy.

NET FARM INCOME

Production from new cropland on marginal, submarginal, and Soil Bank land resulted in a net increase of $4.5 million in net farm income annually (Table 21). This figure is referred to as a net increase because it accounts for the income from woodland and pastureland that is foregone to produce crops. In other words, it shows how much additional net farm income was generated from crops over the income that would have been generated if land use had not changed. Although the net income is an annual flow, it will fluctuate from year to year depending on such factors as prices received, prices paid, and average yield per hectare.

The increased net income per hectare for all marginal and submarginal land averaged $26 compared to $80 for Soil Bank land classified as suitable for production (Table 21). The smallest difference in increased net income between these two classifications occurred in the Atlantic Coast Flatwoods. For all marginal, submarginal, and Soil Bank land, average net income per hectare increased $61 in crop production over other uses.

Aggregate net farm income increased $2.4 million in the Southern Coastal Plain as a result of placing marginal, submarginal, and Soil Bank land in crop production. Net farm income increased $1 million in the Piedmont, $0.7 million in the Atlantic Coast Flatwoods, and $0.4 million in the Appalachian Valley.

AGGREGATE ECONOMIC EFFECTS

Increased agricultural production and farm income affect not only agriculture but also many other sectors of a state's economy. The most direct effect is on firms that supply inputs to agriculture and firms that process agricultural products. Income and employment in these agribusiness firms

TABLE 20. ESTIMATED PRODUCTION FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL, AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare	Total	Average per Hectare
	(1,000 Dollars)	(Dollars)	(1,000 Dollars)	(Dollars)	(1,000 Dollars)	(Dollars)
Appalachian Valley and Ridges	143.76	277.67	1,183.73	362.82	1,327.49	351.15
Mountain	8.63	246.98	38.19	370.87	46.82	340.28
Piedmont	765.85	249.40	3,104.02	344.73	3,869.87	320.49
Sand Hills	400.65	191.92	355.68	316.19	756.33	235.44
Southern Coastal Plain	4,210.76	225.16	8,968.08	400.57	13,178.84	320.74
Atlantic Coast Flatwoods	4,055.12	309.12	388.62	367.98	4,443.74	313.50
State Total	9,584.76	255.40	14,038.32	380.04	23,623.08	317.23

*Includes marginal and submarginal Soil Bank land.

TABLE 21. ESTIMATED INCREASED NET FARM INCOME FROM NEW CROPLAND ON MARGINAL, SUBMARGINAL, AND SOIL BANK LAND IN GEORGIA, 1976

Land Resource Area	Marginal and Submarginal Land*		Cultivatable Soil Bank Land		Marginal, Submarginal and Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare	Total	Average per Hectare
	------------------------------(Dollars)------------------------------					
Appalachian Valley and Ridges	35,074	68	367,346	113	402,420	106
Mountain	-297	-9	5,284	51	4,987	36
Piedmont	114,424	37	869,684	97	984,108	81
Sand Hills	-7,000	-3	69,543	62	62,543	19
Southern Coastal Plain	298,219	16	2,119,807	95	2,418,026	59
Atlantic Coast Flatwoods	591,579	45	65,687	62	657,266	46
State Total	1,031,999	26	3,497,351	80	4,529,350	61

*Includes marginal and submarginal Soil Bank land.

are directly linked to agricultural production. The effects of increased production do not, however, stop here, as agribusiness firms purchase from other industries and workers in agriculture and agribusiness spend their money for goods and services produced by other industries.

Analytical procedures to quantify the interindustry flows between agriculture and nonfarm sectors are complex. A model has been developed in this study, however, to quantify the effect of a change in agricultural production on important economic variables. Development and interpretation of the model are presented in Appendix B.

In addition to explaining economic flows, the interindustry model can be used to calculate the impact of increased agricultural production. The actual Georgia situation with respect to all independent variables in the interindustry model was taken as the base situation. Then the effect of placing the 74.5 thousand hectares of marginal, submarginal, and Soil Bank land into crop production was evaluated. It was assumed that (a) production would increase by $23.6 million, (b) farm earnings - net farm income and farm labor earnings - would increase by $6.7 million, and (c) farm purchases would increase by $15.1 million. The effect of these changes were simulated using the interindustry model from Appendix B. Results of this simulation analysis indicate that the increased crop production on marginal, submarginal and Soil Bank land would increase personal income in the state by $9.1 million. One-fourth of the increased personal income resulting from increased crop production accrues to the nonfarm sector.

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APPENDIX A

LANDSAT REMOTE SENSING TO DETERMINE LAND USE CHANGES

One of the more important recent technological advances for scientific research has been the development of a satellite specifically designed to gather information about the earth's resources. Two satellites launched by the National Aeronautics and Space Administration and known as LANDSAT 1 and 2, currently orbit the earth in a systematic fashion every nine days gathering data for virtually every point on the globe. This new source of data has important implications for research on natural resource use.

Researchers interested in monitoring natural resource use have applied LANDSAT imagery to many problems. The U.S. Department of Agriculture, the National Oceanic and Atmospheric Administration, and NASA have created LACIE (Large Area Crop Inventory Experiment) to help accurately forecast harvests on a global scale. After one year of operation, the system implemented to handle and analyze LANDSAT data demonstrated promise (MacDonald, Hall and Erb, 1975). In the state of Washington, researchers have found that computer-aided interpretation of LANDSAT data offers natural resource land planners an unparalleled opportunity to examine land cover of large areas (Scott and Harding, 1975). In another application, Klemas and Bartlett used satellite imagery to map and inventory the significant ecological communities of Delaware's coastal zone and concluded that data products were accurate and could be easily used by researchers, planners, and government officials.

The purpose of this appendix is to report on the potential for using LANDSAT remote sensing data to determine changing rural land use patterns. This study focuses on the practical utility of using satellite imagery as a primary source of information for determining land cover changes on an intertemporal basis. The research experience reported here should be helpful to other researchers contemplating implementation of LANDSAT imagery for similar purposes.

Central to any decision to implement LANDSAT data, of course, is a basic understanding of how the satellite works, what kind of information it collects, and a knowledge of its advantages and limitations. On board the spacecraft is a multispectral scanner that records reflected energy from the earth and channels it through an optical system to detectors sensitive to four different bands of the spectrum (three of the bands are in the visible portion of the electromagnetic spectrum and the fourth is in the near infrared). The detectors measure the light intensities of 0.4 hectare picture elements called pixels and convert the reflected light from these pixels into electric voltages. A digitizer then translates the impulses into computerdigestible number values from zero to 63 and the data are transmitted to receiving stations, recorded on tape, and shipped to a central processing facility at Goddard Space Flight Center.

These LANDSAT data are grouped into LANDSAT scenes. Each scene is approximately 185 by 185 kilometers and covers an area of 3.4 million hectares or 34,253 square kilometers. LANDSAT surveys one scene in 25 seconds, a speed that is quite remarkable as one scene contains more than 7.5 million pixels per band or approximately 30 million pixels for all four bands. Computer comptabile tapes and 23 by 23 centimeter transparencies that correspond with a particular scene can be ordered from the Earth Resources Observation System (EROS) facility in Sioux Falls, South Dakota.

In agriculture, researchers can identify several different types of crops with considerable accuracy in fields as small as 8 hectares. Success in classifying land cover using the LANDSAT data depends to a large degree on the quality of "ground truth" information. Ground truth is land cover that is actually identified by fieldwork. When this information is compared with the satellite image of a small area, researchers can verify what the pixels in the image represent and can then use computer analysis to extrapolate those results to much larger areas (Bishop, 1976).

Aside from the almost limitless number of possibilities and applications in resource management, technical advantages of LANDSAT are that the data are multispectral, temporal, synoptic, and near orthographic. The synoptic character of LANDSAT images refers to the fact that LANDSAT imagery covers enough area to show a wide range of land characteristics. The near-orthographic quality of LANDSAT images means that overlays of controlled base maps fit the images with minimum of distortion. Thus they have properties not previously available in aircraft photography. Limitations of LANDSAT data, however, include lower resolution than aircraft imagery, atmospheric attenuation and, because data are collected at fixed intervals, cloudy or stormy weather cannot be avoided. Additional information on the technical aspects of LANDSAT data is discussed in Westin and Frazee's article on the use of satellite imagery in a soil survey program.

Special consideration must be given to the dates of the satellite images used. Based on NASA training workshops at Bay St. Louis, Mississippi and conversations with personnel of the Georgia Department of Natural Resources and Engineering Experiment Station at Georgia Tech, mid-summer was judged to be the most favorable time to classify land cover using LANDSAT imagery. During mid-summer most row crops would have sufficient growth to be distinguished from bare ground. With winter scenes, it would be difficult to distinguish between idle and cultivated land. Also, some land used for row crops might be double cropped with such close grown crops as wheat, barley, and rye during the winter. A fall scene would include some crops that had already been harvested; other crops would be almost ready for harvesting. Imagery with no cloud cover or haze is, of course, the best imagery to obtain. It was believed, however, that imagery with some cloud cover could be used if the clouds were not over the area to be analyzed.

Ground truth information was collected and delineated for this study on U.S. Geological Survey topographic maps (7.5 min. quad sheets) so that accurate Universal Transverse Mercator (UTM) coordinates for specific fields could be noted and entered into the computer. The ground truth information consisted of several large fields of each major type of land cover. Experience with processing LANDSAT data revealed that large fields located near salient land features such as rivers, lakes, and crossroads provided the best ground truth.

Because LANDSAT scenes for two different time periods do not exactly correspond, the data must be geographically referenced to the UTM coordinate system. This procedure allows the data to be superimposed to determine areas in which land cover changes have taken place between the dates of two LANDSAT passes. For this study, researchers located prominent ground features on black and white photographs that were supplied with each scene, found their UTM coordinates, and assisted the computer scientist in locating these points on an image display screen. After a LANDSAT scene was geographically referenced on the computer, "training samples" were identified. Homogeneous areas such as centers of lakes, woodland, and corn fields were selected from the image display screen for input into computer programs that can statistically determine these various land cover types for other areas in the scene. Accurate ground truth information is essential in the process of selecting most of the training samples because the computer would classify a much larger area based on the samples.

APPENDIX B

INTERINDUSTRY MODEL OF GEORGIA'S STATE ECONOMY

The purpose of the research reported in this Appendix is to develop an econometric model of interindustry economic flows for state economies. Attention is focused on the role of the agricultural sector in the overall economy. Realizing that modeling economic systems is enormously complex, the principal economic characteristics of the economy are emphasized.

RELATED LITERATURE

National Models

Previous studies have developed large econometric models of the agriculture sector. Early work includes models by Fox, Cromarty, and Evans but these full-size agricultural sector models have not been incorporated into large macromodels. Although these models have been useful in analysis of agriculture in the past, the increasingly important contribution of agriculture to the general economy as well as macroeconomic effects on agriculture have caused use of such models to be increasingly limited.

Recent studies have sought to link the agricultural sector to the macroeconomy. Chen constructed the Wharton Agricultural Model using quarterly data and 22 structural equations. The model simultaneously determined quarterly equations of supply, demand, inventory, and price relations for 17 commodities or commodity groups. Annual crop production was projected using annual and recursive equations in the annual crop production block. The income and expenditure accounts for the agriculture sector were basically definitional. The micro-macro linkage block treats the agricultural sector as other production sectors of the economy by connecting aggregate demand components, labor and employment, wages, and income. A full feedback relationship between the agricultural sector and macromodel results from these connections. Roop and Zeitner have also constructed an agricultural sector model compatible with the Wharton macromodel. They base their model on the income statement as used in the National Income and Product Accounts. Nine behavioral equations were specified to replace the five agricultural equations in the original Wharton model. The nine equations include gross farm product, farm sector income, net proprietors' farm income, cash receipts, investment employment, implicit sector deflator, wage compensation per man-year, and depreciation expense.

An examination of national models linking the agricultural sector to nonfarm sectors may prove useful for formulating state models. However, many of the relationships identified in this manner would be considerably less important for area models than for a national model. Hence, it would be inappropriate to reestimate these models for state economies without considerable reformulation. Also, the detail in the nonfarm sectors of these models is really not needed for the purposes of this study.

State Models

The most frequently used form of macroeconomic model at the state and also sub-state levels has been input-output (I-O) analysis. Input-output applications have been numerous and the basic techniques for constructing input-output tables are described in detail in Heady and Candler and Miernyk.

Several I-O models have been constructed in Georgia for different levels of aggregation over regions and over sectors. These are discussed by Langley, Schaffer, et al., Joncker, and Liu. Effects of variation in the number of sectors in an I-O model have been explored by Doeksen and Little in a simulation study in which they found that multiplier estimates were comparable among all models regardless of aggregation level.

The economic flows among sectors have been the subject of several input-output (I-O) studies in Georgia. Langley constructed the first input-output study of Georgia in 1969. His model consisted of 14 sectors, 12 of which were agribusiness sectors. The other sectors were farming and all-other industry. Schaffer, Laurent, and Sutter constructed the largest Georgia I-O table in 1970 containing 50 sectors.

A principal problem in all I-O studies has been the high cost of constructing transaction tables describing economic flows in the model. The minimum cost of constructing an acceptable I-O model for the state of Georgia has been estimated to be $100 thousand (Schaffer, Laurent, and Sutter, 1972). Even at this cost the process would consist mainly of adjusting a national I-O table to Georgia conditions.

Several adjustment techniques have evolved to use I-O coefficients in sub-regions of an area that may have an existing current model. Morrison and Smith in a recent review of techniques concluded that a simple location quotient technique is very inexpensive and can be used with ordinarily available secondary data sources. Accuracy of the simple location quotient, (LQ), method, however, has been questioned. Miller and Liu compared estimates from a location quotient model with location quotient results corrected by surveys of imports and exports and concluded that there were significant errors in the unadjusted LQ method. Survey techniques for adjusting existing models have also been devised and recommended by Czamanski and Malizia.

As the major importance of I-O models is to estimate the aggregate impacts on multipliers of exogenous changes occurring in a single sector of the economy, there remains a demand and possibility that aggregate multipliers can be estimated by econometric techniques applied to available data.

CONCEPTUAL FRAMEWORK

This survey of recent work suggests a possible comparison between the major economic flows of an area and similar transactions in an I-O table. Examining some of the important flows in an I-O framework may help to specify variables and equations in an appropriate econometric model.

In a closed I-O model, major interactions are found between agriculture, basic industry, service industry and households. The model, however, is open with respect to all exports from the area and all imports. As pointed out in all I-O discussions, an important characteristic of the economy is that the equilibrium flows are simultaneously determined. Agriculture's purchases from basic industry are significant; energy, fertilizer, insecticides and mechanization have been at the forefront of agricultural growth. In state economies, however, most farmers' purchases of these items are from service industries such as petroleum wholesalers, fertilizer dealers, and farm supply stores in general. Thus, the principal payments of agriculture are to service industry, for imports of primary inputs and earnings from farming paid households in the area. Basic industry would of course be the primary buyer of most agricultural products. But again in states, agricultural outputs are likely to move through a service industry buyer and from there into regional, national and even world markets before eventually being utilized by basic industry.

Local households, as an endogenous sector of a closed model would be expected to purchase very little, if any, goods from local agriculture and local manufacturing. Most of their incomes will be spent for goods filtered through wholesale and retail trade and other service industries.

Specific transaction data are not generally available to describe input-output flows. As indicated by previous studies, our current data systems are not designed to collect data of this type. A great amount of data is collected, however, that records the results of similar flows described by I-O. Thus, conceptually it is possible to specify a set of simultaneous relationships based on economic theory and results of prior I-O studies that will approximately describe aggregate flows and impacts of the same type found by I-O.

MODEL SPECIFICATION

Total employment, labor earnings, and personal income are thought to be key performance variables. An economic model that describes the interrelationships among these variables is described below. The model includes four behavioral relationships and four identities.

Much evidence from prior modeling, particularly I-O, indicates that total basic employment and total service employment are determined simultaneously. The principal exogenous determinant of employment in basic industries is most likely national demand for output (or shipments) from these industries. Although service employment is a function of basic employment, it is also expected to be positively related to the level of agricultural input purchases. Algebraically, these employment relationships can be stated as follows (where X_j represents additional variables that may be found to affect the basic flows):

$$\text{Basic employment} = f_1\ (\text{Service employment; Value of shipments, } X_j) \tag{B-1}$$

$$\text{Service employment} = f_2\ (\text{Basic employment; Farm input purchases, } X_j) \tag{B-2}$$

Determination of the wage structure or even the average wage is far beyond the scope of this study. Earnings in the basic and service industries are, therefore, the product of the exogenous industry wage and endogenous level of employment.

$$\text{Basic earnings} = (\text{Basic wage})\ (\text{Basic employment}) \tag{B-3}$$

$$\text{Service earnings} = (\text{Service wage})\ (\text{Service employment}) \tag{B-4}$$

Total earnings are the sum of earnings determined from basic service industries and exogenously determined earnings of agriculture and federal, state and local government workers. Farm earnings are probably not endogenously related to other earnings in a state or sub-state economy, but are probably related almost entirely to farm profits. Hence, the total earnings equation can be expressed as the following identity.

$$\text{Total earnings} = \text{Basic earnings} + \text{Service earnings} + \text{Farm earnings} + \text{Government earnings} \tag{B-5}$$

Personal income is endogenously determined as a function of local earnings from employment and from holdings of capital wealth. Income from non-local activities would be small relative to local and probably randomly associated with income observations at the state level of aggregation.

$$\text{Personal income} = f_3\ (\text{Total earnings; Wealth, } X_j) \tag{B-6}$$

Per capita personal income, which will be used to determine retail trade, can be calcualted directly from total personal income as follows.

$$\text{Per capita personal income} = \frac{\text{Personal income}}{\text{Population}} \tag{B-7}$$

Retail sales are a function of per capita personal income and the size of population. While not all local income is expended locally, a major portion will be in most areas. Anderson has shown this hypothesis to hold even for sub-state levels.

$$\text{Retail sales} = f_4\ (\text{Per capita personal income; Population, } X_j) \tag{B-8}$$

DATA

The model described above was estimated for state economies for 1975 using cross-sectional data from the 48 contiguous states. Employment and earnings by industry group for each state were obtained from Employment and Earnings (U.S. Bureau of Labor Statistics, 1976). Personal income by state was reported in Survey of Current Business (U.S. Bureau of Economic Analysis, 1976). Farm sales and farm input purchases were obtained from State Farm Income Statistics (U.S. Department of Agriculture, 1976). The wealth variable used in this study was net worth of top wealth holders by states reported in Personal Wealth (U.S. Internal Revenue Service, 1974). The rest of the data including value of shipments in manufacturing, population, density, and retail trade was reported by U.S. Bureau of the Census.

RESULTS

The model was estimated in logarithms using three-stage least squares. The logarithm model was chosen (a) to provide for nonlinearities, (b) to account for interactions among explanatory variables, and (c) most importantly, to measure marginal rather than average effects of explanatory variables. Marginal impacts are important in this study, because we are interested in measuring the effects of changes in agricultural production on the overall economy.

When both the dependent variable and explanatory variable are in logarithms, the regression coefficient is an elasticity; however, the elasticity can be converted to a marginal effect:

$$ME = b\ D^*/X^* \tag{B-9}$$

where

ME is marginal effect

b is a regression coefficient and an elasticity

D* is a specified level of the dependent variable

X* is a specified level of the explanatory variable

In the following discussion, the elasticities were converted to marginal effects using geometric means for the sample. Because of the structure of this model, both direct and indirect effects (multipliers) will be forecasted by the model. The regression coefficients themselves can be interpreted as producing direct effects, whereas the reduced form coefficients would indicate both direct and indirect effects. Estimates of the direct effects are discussed below.

The estimates for the parameters of the model are presented in Table B1. Student's t-values and the level of statistical significance for each regression coefficient are also reported in the table. In general, the model did a good job in explaining variation in all the behavioral equations, and almost all of the variables are significant at the 0.01 level. Only the wealth variable is not statistically significant; however, the size of the t-value (1.4) and the expected positive sign indicates that the variable may reasonably be maintained. Its lack of significance can probably be attributed to the fact that the variable does not fully reflect productive wealth. The variable is kept in this equation to indicate the need for an adequate measure of productive wealth.

The linkage of the agricultural sector to earnings and employment in the overall economy will be considered first. Exogenous changes in net farm income and farm labor earnings are included in the total earnings identity, equation (B-5). Each dollar increase in farm earnings directly raises per-

TABLE B1. ESTIMATED PARAMETERS FOR INTERINDUSTRY MODEL OF STATE ECONOMIES, 1975

Variable	Estimated Parameter	Student t-value
Equation (B-1) Dependent Variable - Basic Employment in Logarithms		
Intercept	0.0968	9.7864*
Service employment (endogenous) in logarithms	0.4279	5.2822*
Manufacturing value of shipments in logarithms	0.5624	8.6893*
Equation (B-2) Dependent Variable - Service Employment in Logarithms		
Intercept	2.7829	4.7972*
Basic employment (endogenous) in logarithms	0.6236	12.6587*
Total farm input purchases in logarithms multiplied by relative importance of farming	0.1671	4.8328*
Percentage of population that is metropolitan	0.0101	5.2911*
Equation (B-6) Dependent Variable - Personal Income in Logarithms		
Intercept	1.3286	4.9736*
Total earnings (endogenous) in logarithms	0.9742	51.1577*
Wealth in logarithms	0.0241	1.3672*
Equation (B-8) Dependent Variable - Retail Sales in Logarithms		
Intercept	1.6937	4.8624*
Per capita personal income (endogenous) in logarithms	0.5510	8.0363*
Population in logarithms	0.9667	111.7537*

*Indicates a statistical significance at a level of 1 percent.

sonal income by $1.30. Service employment is directly related to the level of farm input purchases. The variable used to capture this relationship is the logarithm of input purchases multiplied by the relative importance of agriculture in a state's economy. Using sample averages, each $1 million in farm input purchases directly increased service employment by 106 jobs.

An examination of the employment equations indicates that an increase in basic employment will have a large direct impact on service employment. Each one hundred new jobs in basic industries will result in 117 new jobs in service industries, on the margin. One hundred new jobs in service industries, however, will require only 23 more workers in basic industries within the state.

Some other results should also be mentioned. The marginal effect of total earnings is $1.30 in the personal income equation and appears to be consistent with the national income accounts because personal income consists of more than the sum of earnings. The marginal effect of personal income on retail trade, 0.38, is lower than some estimates of the marginal propensity to consume, but this should be expected because retail trade is not a complete measure of consumption.

In addition to explaining economic flows, the interindustry model can be used to calculate agricultural production multipliers. The agricultural production multiplier, which shows the change in personal income resulting from a one unit change in farm sales, was calculated for Georgia and compared with estimates given by Schaffer, Laurent, and Sutter. They reported that each dollar of final sales resulted in an increase of personal income by 71¢ on the average. As expected, the marginal effect of farm sales is somewhat lower than this average estimate. The agricultural production multiplier, which for this model may be interpreted as showing both the direct and indirect change in personal income resulting from a dollar change in farm sales, was estimated to be 51¢ on the margin for Georgia.

APPENDIX C

LAND RESOURCE INVENTORY FOR GEORGIA

TABLE C1. SOIL RESOURCE GROUPS (SRGs) OF GEORGIA

	Name	% Slope*	Dominant Capability Class & Subclass#	Hydro- Group**	Suitability## Rowcrops	Suitability## Pasture	Suitability## Woodland	Erod. Factor†	Soil Classification††
1.	Ailey	5-12	4s	B	5	3	3	.20	Ultisols
2.	Americus	12-25	7s	A	5	5	3	.17	Ultisols
3.	Angie	0-5	2e	C	3	3	1	.32	Ultisols
4.	Ardilla	0-5	2e	C	3	1	1	.24	Ultisols
5.	Ashe	>60	7s	B	6	6	3	.24	Inceptisols
6.	Bayboro	0-5	5w	D	4	3	1	.17	Ultisols
7.	Bibb	0-5	5w	C	3	3	1	.20	Entisols
8.	Bladen	0-5	5w	D	5	3	1	.10	Ultisols
9.	Boswell	5-12	4e	D	5	3	3	.43	Alfisols
10.	Carnegie-1§	5-12	4e	B	3	3	1	.28	Ultisols
11.	Carnegie-2	12-25	4e	B	3	3	1	.28	Ultisols
12.	Cartecay	0-5	5w	C	3	1	1	.28	Entisols
13.	Cecil	5-12	2e	C	1	1	1	.32	Ultisols
14.	Chewacla	0-5	4w	C	4	3	1	.32	Inceptisols
15.	Conasauga	5-12	6e	C	3	3	3	.43	Alfisols
16.	Cowarts-1	5-12	4e	C	3	1	1	.24	Ultisols
17.	Cowarts-2	12-25	6e	C	4	3	3	.24	Ultisols
18.	Craven	0-5	3e	C	1	1	3	.37	Ultisols
19.	Dotahn	5-12	2e	B	1	1	1	.24	Ultisols
20.	Echaw	0-5	5w	B	5	4	3	.10	Spodosols
21.	Esto-1	5-12	4e	B	3	3	3	.32	Ultisols
22.	Esto-2	12-25	6e	B	5	3	3	.32	Ultisols
23.	Etowah	5-12	3e	B	1	1	1	.37	Ultisols
24.	Fuquay	5-12	3s	B	3	1	1	.20	Ultisols
25.	Faceville	5-12	2e	B	1	1	1	.37	Ultisols

(continued)

TABLE C1. (CONTINUED)

Name	% Slope*	Dominant Capability Class & Subclass#	Hydro-Group**	Suitability##			Erod. Factor†	Soil Classification††
				Rowcrops	Pasture	Woodland		
26. Gilead	5-12	6e	C	5	3	3	.17	Ultisols
27. Goldsboro	0-5	2w	B	1	1	1	.20	Ultisols
28. Grady	0-5	5w	B	5	5	1	.10	Ultisols
29. Greenville-1	0-5	4e	B	5	1	1	.24	Ultisols
30. Greenville-2	5-12	2e	B	1	1	1	.24	Ultisols
31. Hartsells	5-12	2e	B	1	1	3	.28	Ultisols
32. Hayesville-1	5-12	2e	B	1	1	1	.20	Ultisols
33. Hayesville-2	12-25	6e	B	4	3	1	.20	Ultisols
34. Hector	25-60	7e	D	6	3	3	.17	Inceptisols
35. Helena	5-12	3e	C	3	1	3	.37	Ultisols
36. Iredell	5-12	2e	D	1	1	3	.20	Alfisols
37. Istokpoga	0-5	3w	D	6	6	6	.01	Histisols
38. Johnson	0-5	7w	D	5	4	1	.20	Ultisols
39. Kershaw	5-12	7s	A	5	5	5	.15	Entisols
40. Kinston	0-5	3w	D	5	2	1	.24	Entisols
41. Lakeland-1	5-12	4s	A	5	3	3	.17	Entisols
42. Lakeland-2	12-25	6s	A	5	3	3	.17	Entisols
43. Leefield	0-5	2w	C	3	3	2	.01	Ultisols
44. Leon	0-5	4w	D	5	5	5	.20	Spodosols
45. Louisburg	12-25	6e	B	6	5	3	.20	Inceptisols
46. Marlboro	5-12	2e	B	1	1	1	.20	Ultisols
47. Mascotte	0-5	4w	D	5	3	3	.20	Spodosols
48. Meggett	0-5	3w	D	4	3	1	.32	Alfisols
49. Mountainburg	25-60	7s	D	6	5	5	.17	Ultisols
50. Nella	25-60	6s	B	6	3	3	.20	Ultisols

(continued)

TABLE C1. (CONTINUED)

	Name	% Slope*	Dominant Capability Class & Subclass#	Hydro-Group**	Suitability##			Erod. Factor†	Soil Classification††
					Rowcrops	Pasture	Woodland		
51.	Norfolk	5-12	2e	B	1	1	1	.17	Ultisols
52.	Ocilla	0-5	3w	C	3	2	3	.17	Ultisols
53.	Oktibeha	5-12	3e	B	3	3	3	.32	Alfisols
54.	Orangeburg-1	5-12	2e	B	1	1	1	.24	Ultisols
55.	Orangeburg-2	12-25	6e	B	5	1	1	.24	Ultisols
56.	Pacolet	12-25	4e	B	4	2	1	.20	Ultisols
57.	Pelham	0-5	5w	B	5	5	1	.10	Ultisols
58.	Saluda	>60	7e	C	6	6	3	.20	Ultisols
59.	Shack-1	5-12	2e	B	1	1	3	.28	Ultisols
60.	Shack-2	25-60	6e	B	5	5	3	.28	Ultisols
61.	Tallapoosa-1	12-25	6e	C	6	5	3	.28	Ultisols
62.	Tallapoosa-2	25-60	7e	C	6	5	3	.28	Ultisols
63.	Tidal Marsh	0-5	7w	D	6	6	6	.01	Histisols
64.	Tifton-1	0-5	2e	B	1	1	1	.24	Ultisols
65.	Tifton-2	5-12	3e	B	1	1	1	.24	Ultisols
66.	Townley-1	5-12	4e	C	3	3	3	.37	Ultisols
67.	Townley-2	12-25	6e	C	6	3	3	.37	Ultisols
68.	Transylvania	0-5	2e	B	1	1	2	.32	Inceptisols
69.	Troup-1	0-5	3e	A	4	3	3	.17	Ultisols
70.	Troup-2	5-12	4s	A	4	3	3	.17	Ultisols
71.	Vaucluse-1	5-12	4e	C	5	3	3	.17	Ultisols
72.	Vaucluse-2	12-25	6e	C	5	3	3	.17	Ultisols
73.	Wagram	5-12	2s	A	3	1	1	.15	Ultisols
74.	Urban Area	0-5	8s	D	6	6	6	0	Ultisols

(continued)

TABLE C1. (CONTINUED)

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[*] % Slope - source is from average slope of soil associations taken from USDA/SCS soil association map.

[#] Dominant Capability Class and Subclass - source is from SCS where the class and subclass, which best fit the midpoint of the average slope range for each soil association, was assigned to that complete mapping unit, later to be called a Soil Resource Group.

[**] Hydro-Group - source is from soil series data provided by SCS.

Hydrologic soil group
A = low runoff
B = moderate runoff
C = moderately high runoff
D = high runoff

The different infiltration characteristics of soils are accounted for by classifying soils into four hydrologic soil groups based on the minimum rate of infiltration obtained for bare soil after prolonged wetting.

[##] Suitability - source is from published soil survey data.

rated for potential continuous crop production
1 = good
2 = fair-good
3 = fair
4 = poor-fair
5 = poor
6 = unsatisfactory

[†] Erodibility Factor - source is from published soil survey data. Soil-erodibility factor is the average soil loss per unit of erosive rainfall (R) under arbitrary selected conditions and depends on soil properties.

[††] Soil Classification - source is from SCS published soil survey data. All soils belong to one of 10 major orders of soils according to an international soil classification system.

[§] Some SRG's have the same name but different slopes.

TABLE C2. TOTAL HECTARES FOR EACH SOIL RESOURCE GROUP AND LAND RESOURCE AREA IN GEORGIA*

Soil Resource Group	Land Resource Area						
	Appalachian Valley and Ridges	Mountain	Piedmont	Sand Hills	Southern Coastal Plain	Atlantic Coast Flatwoods	Total
			(Hectares)				
1. Ailey				1,238			1,238
2. Americus					64,282		64,282
3. Angie					15,789		15,789
4. Ardilla					5,167		5,167
5. Ashe		193,349					193,349
6. Bayboro						53,477	53,477
7. Bibb				31,297	50,009		81,306
8. Bladen					11,114	148,898	160,012
9. Boswell					19,014		19,014
10. Carnegie-1#					27,284		27,284
11. Carnegie-2					16,637		16,637
12. Cartecay	58,455	20,249	528,667				607,371
13. Cecil			2,194,390				2,194,390
14. Chewacla				15,577	127,258	33,055	175,890
15. Conasauga	73,284						73,284
16. Cowarts-1				84,639	308,589		393,228
17. Cowarts-2					30,368		30,368
18. Craven					15,922		15,922
19. Dothan				39,489	841,471		880,960
20. Echaw						27,360	27,360
21. Esto-1					44,188		44,188
22. Esto-2					124,093		124,093

(continued)

TABLE C2. (CONTINUED)

Soil Resource Group	Appalachian Valley and Ridges	Mountain	Piedmont	Sand Hills	Southern Coastal Plain	Atlantic Coast Flatwoods	Total
			(Hectares)				
23. Etowah	29,381						29,381
24. Fuquay					115,660		115,660
25. Faceville					155,475		155,475
26. Gilead				24,699	130,014		154,713
27. Goldsboro					16,193		16,193
28. Grady					23,263		23,263
29. Greenville-1				20,307			20,307
30. Greenville-2				23,639	356,696		380,335
31. Hartsells	20,044						20,044
32. Hayesville-1		57,965					57,965
33. Hayesville-2		111,266					111,266
34. Hector		19,723					19,723
35. Helena			20,394		17,839		38,233
36. Iredell			41,552				41,552
37. Istokpoga						214,798	214,798
38. Johnson						177,844	177,844
39. Kershaw					60,906	39,139	100,045
40. Kinston					324,090	24,499	348,589
41. Lakeland-1				334,144	186,572	137,823	658,539
42. Lakeland-2				58,576	40,873		99,449
43. Leefield					66,821	663,980	730,801
44. Leon						33,673	33,673
45. Louisburg			115,567				115,567

(continued)

TABLE C2. (CONTINUED)

Soil Resource Group	Land Resource Area: Appalachian Valley and Ridges	Mountain	Piedmont	Sand Hills	Southern Coastal Plain	Atlantic Coast Flatwoods	Total
				(Hectares)			
46. Marlboro					40,242		40,242
47. Mascotte						616,996	616,996
48. Meggett				13,129	151,623	19,696	184,448
49. Mountainburg			30,090				30,090
50. Nella	139,416						139,416
51. Norfolk					425,621		425,621
52. Ocilla						73,389	73,389
53. Oktibbeha					21,663		21,663
54. Orangeburg-1				7,181	426,841		434,022
55. Orangeburg-2					82,251		82,251
56. Pacolet			1,286,755				1,286,755
57. Pelham					9,850	42,351	52,201
58. Saluda	728	107,121					107,849
59. Shack-1	107,905						107,905
60. Shack-2	179,254						179,254
61. Tallapoosa-1			157,222				157,222
62. Tallapoosa-2		138,966					138,966
63. Tidal Marsh						207,091	207,091
64. Tifton-1						153,517	153,517
65. Tifton-2					1,184,636		1,184,636
66. Townley-1	32,180						32,180
67. Townley-2	112,144						112,144
68. Transylvania		3,731					3,731
69. Troup-1						39,455	39,455
70. Troup-2					62,040		62,040

(Continued)

TABLE C2. (CONTINUED)

Soil Resource Group	Land Resource Area: Appalachian Valley and Ridges	Mountain	Piedmont	Sand Hills	Southern Coastal Plain	Atlantic Coast Flatwoods	Total
	(Hectares)						
71. Vacluse-1					3,560		3,560
72. Vacluse-2				112,573			112,573
73. Wagram					175,345		175,345
74. Urban area			19,594				19,594
Total	752,791	652,370	4,394,231	766,488	5,779,259	2,707,041	15,052,180

*Source: U. S. Department of Agriculture, Soil Conservation Service. Soil Association Map of Georgia. Athens, Georgia, 1977.

#Some Soil Resource Groups have the same name but different slopes.

TABLE C3. CULTIVATABLE, MARGINAL, WETLANDS AND SUBMARGINAL LANDS IN ROW CROPS BY LAND RESOURCE AREA*

Land Resource Area	Cultivatable (I,II,III)	Marginal (IV)	Wetlands (V)	Submarginal (VI,VII,VIII)	Total	Distribution by Land Resource Area
			(Hectares)			(Percent)
Appalachian Valley and Ridges	53,215	3,132	0	1,172	57,519	3.8
Mountain	10,150	1,274	0	1,443	12,867	0.9
Piedmont	111,217	15,351	181	5,655	132,404	8.8
Sand Hills	39,530	3,860	156	787	44,333	3.0
Southern Coastal Plain	1,036,867	37,445	5,553	6,902	1,086,767	72.7
Atlantic Coast Flatwoods	149,536	9,232	1,850	459	161,077	10.8
Total	1,400,515	70,294	7,740	16,418	1,494,967	100
			(Percent)			
Distribution	93.7	4.7	0.5	1.1	100	

*Source: U.S. Department of Agriculture, Soil Conservation Service. Georgia Conservation Needs Inventory, 1967. Washington, D.C., April, 1970.

TABLE C4. CULTIVATABLE, MARGINAL, WETLANDS AND SUBMARGINAL LANDS IN FOREST BY LAND RESOURCE AREA*

Land Resource Area	Cultivatable (I,II,III)	Marginal (IV)	Wetlands (V)	Submarginal (VI,VII,VIII)	Total	Percent in Each Land Resource Area
			(Hectares)			(Percent)
Appalachian Valley and Ridges	114,136	68,555	0	281,453	464,144	4.8
Mountain	35,272	48,421	234	296,744	380,671	4.0
Piedmont	1,080,431	815,374	12,996	1,035,827	2,944,628	30.7
Sand Hills	191,261	110,692	44,331	142,654	488,938	5.1
Southern Coastal Plain	1,600,516	346,396	895,476	567,246	3,409,634	35.5
Atlantic Coast Flatwoods	620,179	84,465	980,678	228,361	1,913,683	19.9
Total	3,641,795	1,473,903	1,933,715	2,552,285	9,601,698	100
			(Percent)			
Distribution	37.9	15.4	20.1	26.6	100	

*Source: U.S. Department of Agriculture, Soil Conservation Service. Georgia Conservation Needs Inventory, 1967. Washington, D.C., April, 1970.

TABLE C5. CULTIVATABLE, MARGINAL, WETLANDS AND SUBMARGINAL LANDS IN OTHER USES* BY LAND RESOURCE AREA#

Land Resource Area	Cultivatable (I,II,III)	Marginal (IV)	Wetlands (V)	Submarginal (VI,VII,VIII)	Total	Percent in Each Land Resource Area
			(Hectares)			(Percent)
Appalachian Valley and Ridges	96,738	35,142	0	30,866	162,746	6.0
Mountain	37,968	12,330	0	16,948	67,246	2.5
Piedmont	657,080	189,158	2,186	108,246	956,670	35.3
Sand Hills	88,046	16,067	2,216	5,693	112,022	4.1
Southern Coastal Plain	959,323	87,302	27,169	30,557	1,104,351	40.8
Atlantic Coast Flatwoods	127,425	9,608	21,654	147,813	306,500	11.3
Total	1,966,580	349,607	53,225	340,123	2,709,535	100
			(Percent)			
Distribution	72.6	12.9	2.0	12.5	100	

*Other Uses as used herein include land for conservation use only, pasture and rangeland, orchards, close grown crops and idle land.

#Source: U.S. Department of Agriculture, Soil Conservation Service. Georgia Conservation Needs Inventory, 1967. Washington, D.C., April, 1970.

APPENDIX D

RUNOFF AND SEDIMENT YIELD DATA

TABLE D1. RUNOFF CURVE NUMBERS (CN) FOR SELECTED AGRICULTURAL USES*

Land Use Description	Hydrologic Soil Group			
	A	B	C	D
Cultivated land without conservation treatment	72	81	88	91
Cultivated land with conservation treatment	62	71	78	81
Pasture, range land, meadow	54	70	80	84
Wood or forest land; moderate cover	35	61	74	80

*Source: Georgia State Soil and Water Conservation Committee. Manual for Erosion and Sediment Control in Georgia, Athens, Georgia, 1977.

TABLE D2. RAINFALL EROSION INDEX FACTOR "R" VALUES*

County	R	County	R	County	R
Appling	350	Clay	350	Franklin	300
Atkinson	350	Clayton	300	Fulton	300
Bacon	350	Clinch	350	Gilmer	300
Baker	350	Cobb	300	Glascock	250
Baldwin	250	Coffee	350	Glynn	350
Banks	300	Colquitt	350	Gordon	300
Barrow	300	Columbia	250	Grady	350
Bartow	300	Cook	350	Greene	250
Ben Hill	350	Coweta	300	Gwinnett	300
Berrien	350	Crawford	300	Habersham	350
Bibb	300	Crisp	350	Hall	300
Bleckley	300	Dade	250	Hancock	250
Brantley	350	Dawson	300	Haralson	300
Brooks	350	Decatur	350	Harris	350
Bryan	350	Dekalb	300	Hart	300
Bulloch	300	Dodge	300	Heard	350
Burke	250	Dooly	300	Henry	300
Butts	300	Dougherty	350	Houston	300
Calhoun	350	Douglas	300	Irwin	350
Camden	350	Early	350	Jackson	300
Candler	300	Echols	350	Jasper	300
Carroll	300	Effingham	350	Jeff Davis	350
Catoosa	250	Elbert	250	Jefferson	250
Charlton	350	Emanuel	300	Jenkins	300
Chatham	350	Evans	350	Johnson	300
Chattahoochee	350	Fannin	250	Jones	300
Chattooga	300	Fayette	300	Lamar	300
Cherokee	300	Floyd	300	Lanier	350
Clarke	250	Forsyth	300	Laurens	300

(continued)

TABLE D2. (CONTINUED)

County	R	County	R	County	R
Lee	350	Putnam	250	Walker	250
Liberty	350	Quitman	350	Walton	300
Lincoln	250	Rabun	350	Ware	350
Long	350	Randolph	350	Warren	250
Lowndes	350	Richmond	250	Washington	250
Lumpkin	300	Rockdale	300	Wayne	350
McDuffie	250	Schley	350	Webster	350
McIntosh	350	Screven	300	Wheeler	300
Macon	300	Seminole	350	White	300
Madison	250	Spalding	300	Whitfield	250
Marion	350	Stephens	300	Wilcox	350
Meriwether	300	Stewart	350	Wilkes	250
Miller	350	Sumter	350	Wilkinson	300
Mitchell	350	Talbot	350	Worth	350
Monroe	300	Taliaferro	250		
Montgomery	300	Tattnall	350		
Morgan	250	Taylor	300		
Murray	250	Telfair	350		
Muscogee	350	Terrell	350		
Newton	300	Thomas	350		
Oconee	250	Tift	350		
Oglethorpe	250	Toombs	350		
Paulding	300	Towns	300		
Peach	300	Treutlen	300		
Pickens	300	Troup	350		
Pierce	350	Turner	350		
Pike	300	Twiggs	300		
Polk	300	Union	300		
Pulaski	300	Upson	300		

*Source: Georgia State Soil and Water Conservation Committee. Manual for Erosion and Sediment Control in Georgia, Athens, Georgia, 1977.

TABLE D3. PLANT COVER OR CROPPING MANAGEMENT FACTOR (C)*

Land Use Groups	Examples	Range of "C" values
Permanent vegetation	Protected woodland Prairie Permanent pasture Sodded orchard Permanent meadow	0.0001-0.45
Established meadows	Alfalfa Clover Fescue	0.004-0.3
Small grains	Rye Wheat Barley Oats	0.07-0.5
Large-seeded legumes	Soybeans Cowpeas Peanuts Field peas	0.01-0.65
Row crops	Cotton Potatoes Tobacco Vegetables Corn Sorghum	0.1-0.70
Fallow	Summer fallow Period between plowing and growth of crop	1.0

*Source: Georgia State Soil and Water Conservation Committee. Manual for Erosion and Sediment Control in Georgia, Athens, Georgia, 1977.

TABLE D4. EROSION-CONTROL PRACTICE FACTOR*

Land Slope %	P Values	
	Contouring	Terracing#
2.0-7	0.50	0.10
8.0-12	0.60	0.12
13.0-18	0.80	0.16
19.0-24	0.90	0.18

*Source: Georgia State Soil and Water Conservation Committee. Manual for Erosion and Sediment Control in Georgia, Athens, Georgia, 1977.

#For prediction of contribution to off-field sediment load.

TABLE D5. ESTIMATED SEDIMENT DELIVERY RATIO AS RELATED TO AVERAGE DRAINAGE AREA FOR PERENNIAL STREAM

Land Resource Area	Average Drainage Area (Square Hectares)*	Sediment Delivery Ratio#
Appalachian Valley and Ridges	0.97	0.25
Mountain	0.12	0.36
Piedmont	0.58	0.27
Sand Hills	1.93	0.12
Southern Coastal Plain	1.55	0.13
Atlantic Coast Flatwoods	2.70	0.10

*Source: Basic watershed map established for Georgia in 1959 by SCS, Athens, Georgia.

#Source: J. W. Roehl. Sediment Source Areas, Delivery Ratios, and Influencing Morphological Factors. Commission on Land Erosion. Publication No. 59. International Association of Scientific Hydrology, 1962.

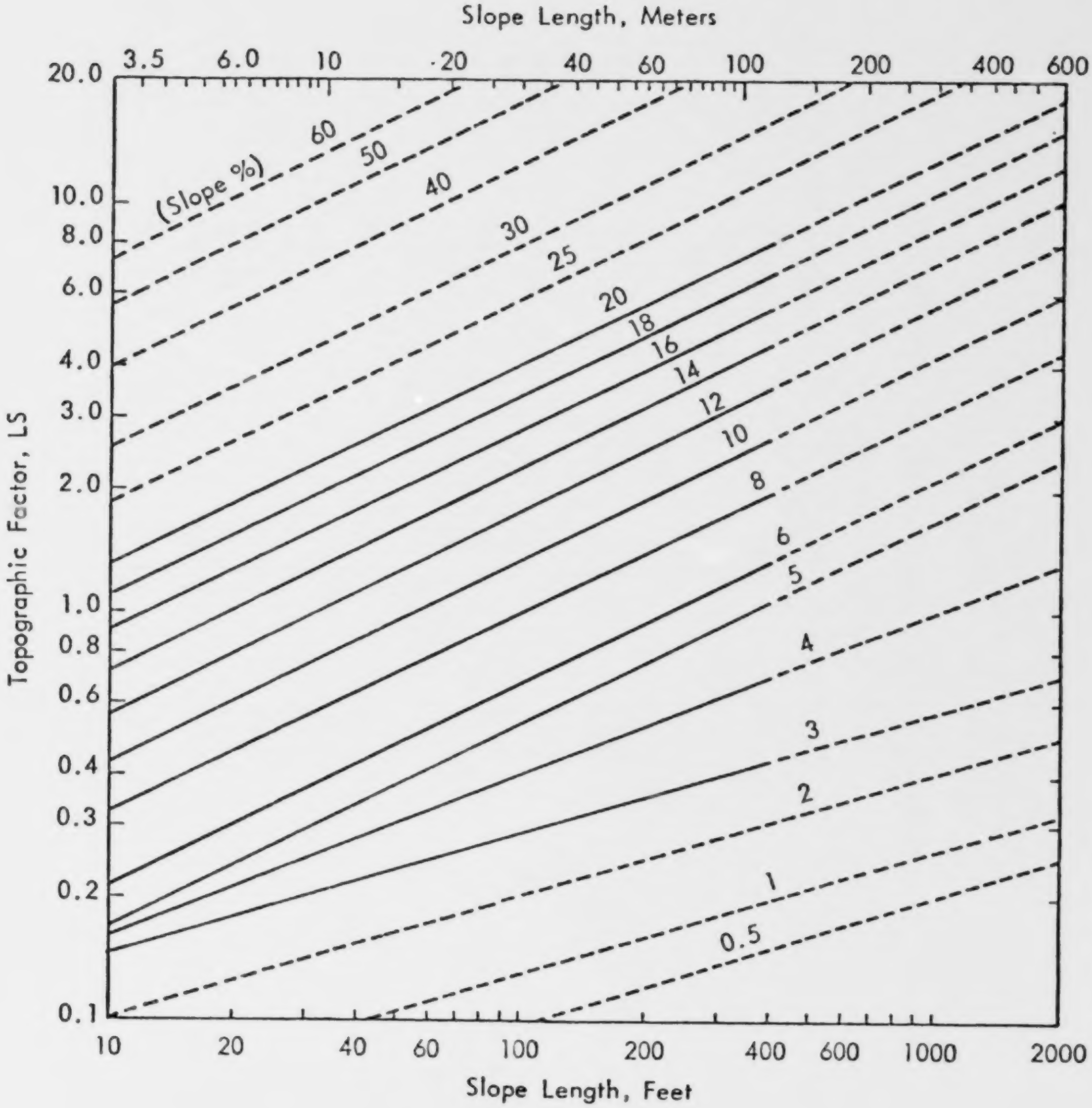

Figure D1. Slope-effect chart.*

*The dashed lines represent estimates for slope dimensions beyond the range of lengths and steepnesses for which data are available.

APPENDIX E

ENVIRONMENTAL IMPACT ON ALL NEW CROPLAND IN GEORGIA

TABLE E1. ESTIMATED RUNOFF FROM NEW CROPLAND IN GEORGIA, 1976

Land Resource Area	All New Cropland		Soil Bank Land	
	Runoff	Increased Runoff	Runoff	Increased Runoff
	(cm)	(cm)	(cm)	(cm)
Land Suitable for Cultivation				
Appalachian Valley and Ridges	6.73	1.55	6.73	1.14
Mountain	9.98	1.70	9.91	1.50
Piedmont	9.47	0.71	9.43	0.36
Sand Hills	10.08	2.03	10.74	1.02
Southern Coastal Plain	8.86	2.85	9.04	1.45
Atlantic Coast Flatwoods	11.38	3.91	11.38	2.41
Total Cultivatable	9.07	2.77	9.07	1.17
Marginal and Submarginal Land				
Appalachian Valley and Ridges	9.04	0.64	8.99	0.33
Mountain	9.60	0.89	-	-
Piedmont	7.62	1.30	7.80	1.04
Sand Hills	5.44	2.61	7.24	1.70
Southern Coastal Plain	8.61	2.51	8.66	1.47
Atlantic Coast Flatwoods	12.24	3.35	10.49	2.16
Total Marginal and Submarginal	9.63	2.69	8.61	1.37
Total State	9.22	2.77	9.02	1.19

TABLE E2. ESTIMATED INCREASED SEDIMENT YIELD FROM NEW CROPLAND IN GEORGIA, 1976

Land Resource Area	All New Cropland		Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare
	(1,000 MT)	(MT)	(1,000 MT)	(MT)
Land Suitable for Cultivation				
Appalachian Valley and Ridges	123.86	27.60	68.88	21.10
Mountain	4.05	23.03	2.35	22.80
Piedmont	431.02	24.64	225.34	25.02
Sand Hills	26.88	7.48	8.54	7.59
Southern Coastal Plain	1,769.37	8.76	218.84	9.77
Atlantic Coast Flatwoods	54.04	1.93	1.74	1.64
Total Cultivatable	2,409.22	9.43	525.69	14.22
Marginal and Submarginal Land				
Appalachian Valley and Ridges	16.16	31.20	8.82	29.14
Mountain	2.11	60.44	0.00	-
Piedmont	96.96	31.56	30.11	30.31
Sand Hills	16.93	8.11	2.11	9.77
Southern Coastal Plain	193.52	10.35	23.87	13.08
Atlantic Coast Flatwoods	8.68	0.67	0.63	1.28
Total Marginal and Submarginal	334.36	8.92	65.54	17.14
Total State	2,743.58	9.36	591.23	14.49

TABLE E3. ESTIMATED SEDIMENT YIELD FROM NEW CROPLAND IN GEORGIA, 1976

Land Resource Area	All New Cropland		Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare
	(1,000 MT)	(MT)	(1,000 MT)	(MT)
Land Suitable for Cultivation				
Appalachian Valley and Ridges	128.29	28.58	70.84	21.71
Mountain	4.18	23.74	2.41	23.45
Piedmont	446.95	25.56	231.78	25.74
Sand Hills	28.21	7.86	8.79	7.82
Southern Coastal Plain	1,865.45	9.25	225.06	10.06
Atlantic Coast Flatwoods	56.95	2.04	1.78	1.68
Total Cultivatable	2,530.03	9.90	540.66	14.63
Marginal and Submarginal Land				
Appalachian Valley and Ridges	16.71	32.26	9.05	29.95
Mountain	2.17	62.07	0.00	-
Piedmont	99.91	32.52	30.86	31.07
Sand Hills	17.59	8.42	2.16	9.99
Southern Coastal Plain	203.29	10.86	24.50	13.42
Atlantic Coast Flatwoods	9.21	0.69	0.64	1.32
Total Marginal and Submarginal	348.88	9.30	67.21	17.58
Total State	2,878.91	9.81	607.87	14.90

TABLE E4. ESTIMATED NITROGEN LOSS FROM NEW CROPLAND IN GEORGIA, 1976

Land Resource Area	All New Cropland Total	All New Cropland Average per Hectare	Soil Bank Land Total	Soil Bank Land Average per Hectare
	(1,000 Kg)	(Kg)	(1,000 Kg)	(kg)
Land Suitable for Cultivation				
Appalachian Valley and Ridges	48.76	10.88	23.14	7.10
Mountain	3.85	21.86	2.29	22.24
Piedmont	205.54	11.76	87.97	9.78
Sand Hills	22.50	6.18	5.93	5.28
Southern Coastal Plain	1,765.76	8.76	213.50	9.54
Atlantic Coast Flatwoods	128.19	4.58	4.16	3.94
Total Cultivatable	2,174.30	8.51	336.99	9.13
Marginal and Submarginal Land				
Appalachian Valley and Ridges	4.62	8.94	2.00	6.62
Mountain	1.82	52.01	0.00	-
Piedmont	44.81	14.60	9.98	10.05
Sand Hills	8.94	4.28	1.46	6.74
Southern Coastal Plain	156.09	8.36	21.86	12.00
Atlantic Coast Flatwoods	52.14	3.98	1.88	3.85
Total Marginal and Submarginal	268.42	7.16	37.18	9.73
Total State	2,442.72	8.34	374.17	9.18

TABLE E5. ESTIMATED PHOSPHORUS LOSS FROM NEW CROPLAND IN GEORGIA, 1976

Land Resource Area	All New Cropland		Soil Bank Land	
	Total	Average per Hectare	Total	Average per Hectare
	(1,000 Kg)	(Kg)	(1,000 Kg)	(Kg)
Land Suitable for Cultivation				
Appalachian Valley and Ridges	105.18	23.45	56.48	17.32
Mountain	4.14	23.58	2.42	23.51
Piedmont	375.63	21.49	188.51	20.94
Sand Hills	25.20	7.02	7.53	6.70
Southern Coastal Plain	1,783.39	8.85	216.19	9.67
Atlantic Coast Flatwoods	56.07	2.00	1.72	1.62
Total Cultivatable	2,349.61	9.21	472.85	12.81
Marginal and Submarginal Land				
Appalachian Valley and Ridges	13.05	25.21	6.89	22.81
Mountain	2.15	61.49	0.00	-
Piedmont	84.13	27.42	24.48	24.67
Sand Hills	14.79	7.09	1.93	8.92
Southern Coastal Plain	186.96	10.00	23.61	12.95
Atlantic Coast Flatwoods	8.66	0.66	0.60	1.23
Total Marginal and Submarginal	309.74	8.25	57.51	15.05
Total State	2,659.35	9.08	530.36	13.01

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